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THE STATUS OF INNOVATIVE TECHNOLOGIES IN ADVANCED MANUFACTURING

HEARING

BEFORE THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

APRIL 12, 2016

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THE STATUS OF INNOVATIVE TECHNOLOGIES IN ADVANCED MANUFACTURING

TUESDAY, APRIL 12, 2016

U.S. SENATE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
Washington, DC.

The Committee met, pursuant to notice, at 10:06 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning. The Committee will come to order this morning.

We have a hearing this morning on the status of innovative technologies in advanced manufacturing. We will be discussing several technologies that are either in place or being developed and some of the discussion may be pretty technical, but I do not think you need to be a rocket scientist to wrap your head around advanced manufacturing.

What is going on in advanced manufacturing is certainly worthy of our attention today. Jobs in these sectors employ almost 24,000,000 people in the United States, approximately 13 percent of our workforce. Advanced manufacturing accounts for about 19 percent of our national GDP with an overall economic impact of around $3.1 trillion per year.

While advanced manufacturing merits attention, we also need to do a better job of preparing a workforce for the high quality jobs that these industries are creating. With 2,000,000 manufacturing jobs projected to be perpetually unfulfilled by 2025, there is a growing skills gap in our country that needs to be addressed.

The reality is that we have both enormous challenges and unprecedented opportunities, and I hope today that we can glean some insights from several perspectives from industry, from universities, and from the market and our national labs on what we can do at the Federal level to positively impact the advanced manufacturing skills gap.

This hearing is also designed to inform us about the significant innovation taking place in advanced manufacturing. So this is, kind of, a look down the road hearing. It is a chance for us to hear about technologies that are emerging, to gauge how they might affect our energy needs, our mineral needs and our workforce development issues, and then to understand the challenges that need to be overcome.

There is certainly a lot happening at the Department of Energy from combined heat and power improvements to research and development in critical minerals to additive manufacturing that has already advanced to the point where fully functional Shelby Cobras can be created via a 3D printer. Totally wild.

With this hearing we will also examine whether Federal programs meant to support innovation are working as intended and whether they are properly oriented to help our advanced manufacturing industries innovate, compete, and thrive.

That brings us to the work that the Advanced Manufacturing Office is doing in collaboration with the national labs, universities and industries. So the questions will be asked. What areas are working best? Which areas can we aim to improve?

I have consistently advocated technology neutral policies for the energy sector, and I would do the same for manufacturing. Instead of picking one favorite technology and plowing most or all of our limited Federal research dollars into it, I am convinced that the better path is to support research into a wider range of possible winners and to let the markets and consumers determine which are best.

I would suspect that our panel today will underscore how crucial that approach is to the advanced manufacturing world.

In this Committee we are on a good track. As a result of our commitment to work together, our bipartisan energy bill includes several provisions to boost innovation in advanced manufacturing. That includes a modified version of the Carbon Fiber Recycling Act, sponsored by Senator Cantwell, and the SMART Manufacturing Leadership Act from Senators Shaheen and Alexander.

I am pleased that we have our witnesses before us today to share their thoughts and comments. I would like to particularly recognize and welcome a friend from Ketchikan, my hometown, here with us today. A long way to talk about advanced manufacturing and what that means in even some very remote and isolated parts of the country, so it is a pleasure to have you all here today.

I will now turn to Ranking Member Cantwell for her comments.

STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Chairman Murkowski, for holding this important hearing, and I thank all the witnesses for being here today. The success of our manufacturing sector is vital to our economy, and during today's hearing we are going to discuss the innovative technologies in advanced manufacturing that you all have been involved in.

I am interested to hear from our panel about recent changes in the manufacturing sector and how technology can improve efficiency, reduce emissions, increase U.S. competitiveness.

Manufacturing is responsible for more than 12,000,000 American jobs and is contributing more than $2 trillion to the U.S. economy and funding 70 percent of the nation's industrial research and development. But to me, these manufacturing jobs, because of the wages they pay, help people who come from working class backgrounds make it to the middle class. So we want to continue these manufacturing opportunities in America.

In my state, ten percent of Washingtonians work in manufacturing, that is 289,000 manufacturing jobs in my home state, and the health of the U.S. manufacturing economy depends on exports.

With middle class around the globe expecting to double by 2030, the market for goods outside the United States is growing and manufacturing is important to the economy but it does face stiff competition from those around the globe. In fact, our international competitors are not standing still. They are accelerating their investments in advanced manufacturing, so U.S. manufacturing needs to continue to build on its strengths.

Our goal is not just to keep or make the cheapest product, but to continue to advance in innovative technologies such as semiconductors, aerospace and innovate faster than others. Prioritizing the innovation and investing in the kind of technologies that will grow jobs is something, I think, that we should all be able to agree on. Because advanced manufacturing harnesses this innovation, makes our businesses more competitive, reduces our energy costs and because energy and natural resources are closely linked together with manufacturing, what we are going to talk about today is very critical.

All manufacturing consumes a large amount of energy and water and leaves behind various waste streams. In fact, the 2015 Quadrennial Review that our Committee had a hearing on, found that manufacturing accounted for 25 percent of energy consumption and 79 percent of industrial energy use. So if we can develop next generation advanced manufacturing technologies right here at home, we will reduce emissions, save energy and assure the competitiveness of our U.S. manufacturing sector.

When we talk about these advanced technologies, there are still challenges that remain. One of the big ones that I saw in the Quadrennial Review, which is almost staggering when you think about it, is the importance of developing a skilled workforce for energy and manufacturing. It is reported in that document that we need an additional 1.5 million new workers over the next 15 years to meet demand. So just training that workforce that we need to be competitive is a goal and challenge in and of itself.

That is why Senator Murkowski and I worked together on the Workforce Title of the Energy bill. We created a workforce training program to incentivize labor and industry to work together and provide training. It makes investment dollars available that would allow an estimated 300,000 individuals over the next four years to receive training and take advantage of new energy and manufacturing job opportunities.

One delight for me is in the area of composite manufacturing where we had created several years ago an advanced composite program at Edmonds Community College. I was delighted last week to be at home and see on the front page a graduate of that program opened up his own aerospace company in Arlington, Washington with a little two-seater hobbyist plane that they are now building there. He had not previously, I think, been in aerospace but had been in another sector, got skilled in composite manufacturing and now we have another manufacturer in our state.

So these are one of the reasons why we need to pass the energy bill because it has some great priorities in there for manufacturing.

The Advanced Manufacturing Office which partners with industry, national laboratories, small businesses, universities, and other stakeholders in new energy efficient processes, can help bring them to scale. The Advanced Manufacturing Office has also focused on new materials, just like the ones I just mentioned before in carbon fiber composites.

But now we need to focus on carbon fiber recycling, and this is something that we were pleased to push through in the energy bill. Recycling carbon fiber reuses left over scrap materials from manufacturing, to help us develop new manufacturing processes. So while we have come a long way on carbon fiber, now we have to figure out the recycling end. Recycling composites only uses one-tenth of the energy compared to actually manufacturing the new fiber composites. So it holds great potential. In Washington State alone, two million pounds of carbon fiber scraps are being sent to landfills each year. If this can be recycled, it has a potential market value of $50 million.

I am pleased that the Advanced Manufacturing Office, along with the Institute for Advanced Composite Manufacturing Innovation at Oak Ridge, will be represented by Dr. Craig Blue, who is working with innovators at the Port of Port Angeles, Washington. I look forward to hearing about this particular area of expertise. The Port is retooling its facilities and workforce to meet the demands of emerging markets and creating good-paying jobs.

I also want to say that I know that we are talking about the FAA bill on the floor, and it has a Center of Materials Excellence at the University of Washington in Aerospace Industry. I am sure we will hear a little bit about this today, the Aerospace Industry is leading the way on 3D printing, the Chairman mentioned this issue.

I am glad that Dr. Christodoulou is here today from The Boeing Company and to talk about the investments that we are making in the future of manufacturing. Boeing was an early adopter of 3D printing technology, and today it has more than 20,000 3D printer printed parts in use with different aircraft. So 3D printing has a potential to change and replace various aircraft parts.

I know it is not just Boeing, but there are many other companies that are using these new applications. One example is Planetary Resources, a space exploration company, using 3D printing to reduce the number of parts on the space craft, making them lighter and more efficient. There are all kinds of examples here today that we are going to hear about where new technology and investment is helping us change manufacturing and, in particular, some of the sectors that I mentioned, obviously big in our state, aerospace.

But there are other industries like shipbuilding that are developing new manufacturing processes, and so I hope that we can talk about how these resources and investments today will help keep those sectors of the U.S. economy very competitive.

Lastly, I just want to mention my colleague, Senator Collins, and I introduced a Federal tax credit incentive for apprenticeships because I think part of meeting this workforce issue is also incenting more apprentice programs in the United States.

I look forward to hearing from the witnesses how we keep our competitive edge in manufacturing today. Such a vital sector of our economy and appreciate everyone's leadership on this issue.

The CHAIRMAN. Thank you, Senator Cantwell.

We will now turn to testimony from our respective witnesses.

We are joined this morning by Dr. Craig Blue, who is the CEO for the Institute for Advanced Composites Manufacturing Innovation as well as Director of the Advanced Manufacturing Office at Oak Ridge, one of our national labs. Welcome, Dr. Blue. We next have Dr. Leo Christodoulou, who is the Director of Engineering for Materials and Structures at The Boeing Company. Welcome.

Dr. CHRISTODOULOU. Thank you.

The CHAIRMAN. As I mentioned my friend from Ketchikan, Mr. Doug Ward, who is the Director of Shipyard Development for Vigor Alaska. Good to have you, Doug.

Dr. David Williams is the Dean of the College of Engineering at Ohio State University. Welcome.

Finally, we have Deborah Wince-Smith, who is the President and CEO for the Council on Competitiveness.

Welcome to each of you and Dr. Blue, if you would like to proceed, please.

We ask that you limit your testimony to five minutes. Your full statements will be included as part of the record.

STATEMENT OF DR. CRAIG BLUE, CHIEF EXECUTIVE OFFICER, INSTITUTE FOR ADVANCED COMPOSITES MANUFACTURING INNOVATION

Dr. BLUE. Okay. Thank you, Senator.

To reiterate, I'm the CEO of the newly-formed composite institute, IACMI, Institute for Advanced Composite Manufacturing. As mentioned prior to that I was at Oak Ridge National Lab where I spent 20 years working hand-in-hand with the industry coupling basic to applied research. I also worked with a team to initiate the manufacturing demonstration facility which has had tremendous success over the last four years with 10,000 visitors and coupling closely to the supply chain and delivering new technology.

IACMI is the fifth manufacturing institute. Second funded by DOE's EERE Advanced Manufacturing Office. The focus of the Institute is on automotive, wind, compressed gas, storage deposits as well as recycling. This is a public/private partnership that catalyzes existing capabilities across the country to enable rapid deployment of high volume composite manufacturing.

The DOE award of $70 million over five years enables an investment of $180 million from states, universities, and companies. The Institute was structured by listening to industry which said that they wanted capability in close proximity to their manufacturing, so we placed our technology focus areas near large concentrations of manufacturing employment.

First in automotive manufacturing is Michigan, so we put our automotive composite technical focus area in Michigan at Michigan State University. Two in the manufacturing area is Ohio. So we put our compressed gas storage at University of Dayton Research Institute. Number three is Indiana so we put our computational and modeling focus area at Purdue. Fourth in manufacturing was Tennessee where we put our materials and processing with the University of Tennessee and Oak Ridge National Laboratory. Our wind focus area was put in Colorado and NREL where there's a significant wind manufacturing ecosystem.

The Composite Institute was launched in June of last year in east—Knoxville where we had over 300 people in attendance. Since then we've had significant success in standing up the new institute. In fact, when we kicked off the institute we had about 120 members. Today we're working on 245.

We've executed 125 agreements and we're working on the second 120, a very good sign.

The geographic footprint and capabilities of IACMI have expanded throughout our partnerships. We signed an MOU with ACMA, the American Composite Manufacturing Association, which represents 500 composite companies in the United States. This expanded our initial footprint where we had partners from 32 states to 50 states.

We also announced a co-location with the Lightweight Innovations for Tomorrow, LIFT, in Michigan. This is where we're going to have our scale up facility for composites for the automotive industry.

At the end of the day these systems are going to be multi material. They'll have magnesium, aluminum, steel and composites. We feel that this is a real strong move.

We signed an MOU with the Composite Prototyping Center in New York which expands our capabilities to the Northeast. And we're working on an MOU with Composite Recycling Technology Center in Port Angeles, a nice ecosystem out there and it takes us to the West Coast.

So more recently, a licensing opportunity was announced by our partner, Oak Ridge National Lab, a commodity based carbon fiber is being produced at half the energy. This is really important because when you look at a carbon fiber composite, 90 percent of entrained energy is actually in the carbon. So this is very exciting.

And then most recently, as in last week, we had a two-day composite training certification program at IACMI headquarters in Tennessee where we had 250 people, I'm sorry, 150 people in with composites one and ACMA, actually getting a certificate to make composites.

The real strength of the institute is aligning manufacturing challenges with U.S. technical and infrastructure capability. Coupling basic and applied research is the key to success. We are identifying composite ecosystems across the county and pulling them in to one composite institute, IACMI.

Thanks.

[The prepared statement of Dr. Blue follows:]

TESTIMONY BEFORE THE SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES, EXAMINING THE STATUS OF INNOVATIVE TECHNOLOGIES IN ADVANCED MANUFACTURING

PRESENTED BY: DR. CRAIG BLUE, CHIEF EXECUTIVE OFFICER, IACMI-THE COMPOSITES INSTITUTE,

SENATE HEARING DATE: APRIL 12, 2016

The Institute for Advanced Composites Manufacturing Innovation (IACMI) is a public-private partnership created to accelerate development of clean energy products, processes, and systems. Specifically, IACMI aims to provide a catalyst to industry, academia, and the public sector, pushing improvements in composites R&D, capitalizing on potential commercial applications, and ensuring continued U.S. leadership in advanced composite manufacturing—a sector that holds significant potential in energy, industry, and American competitiveness.

The IACMI partnership of industry, universities, national laboratories, trade associations, universities, and federal, state and local governments is sharing resources and investing in innovative research nationwide to accelerate development and commercial deployment of advanced fiber reinforced polymer composites. Our growing portfolio of partnerships now gives us members in all 50 states, and our world-class team of leading industrial manufacturers, material suppliers, software developers, government researchers and academics is working toward specific, measurable goals. Specifically, in the next decade, we aim to:

- Lower the cost of advanced composites by 50 percent.
- Reduce the energy used to make composites by 75 percent, and
- Increase the ability to recycle composites by more than 95 percent.

In pursuit of those goals, the Institute is developing new low-cost, high-speed, efficient manufacturing and recycling process technologies and will be training the next generation composite workforce.

The University of Tennessee was selected for negotiations in early 2015 and a cooperative agreement was signed in June of that same year with DOE when IACMI was launched in Knoxville, Tennessee. IACMI is operated by Collaborative Composite Solutions Corporation (CCS Corp.), a wholly-owned not-for-profit subsidiary of the University of Tennessee Research Foundation, and is governed by a board of directors. The institute's structure reflects industry feedback to the Department of Energy and partner institutions, placing R&D and scale-up capability in close proximity to manufacturing sites. We selected sites focused on specific areas of technology, based on factors such as RD&D and jobs.

- Michigan's number-one ranking in automotive RD&D spending and jobs solidified the state as the location for our Vehicle Technology Area.
- Ohio was second in those rankings and is home to our Compressed Gas Storage Technology Area.
- Indiana ranks third and comprises the Modeling and Simulation Technology Area.
- Tennessee ranks fourth and is headquarters for the Material and Processing Technology Area.
- Finally, Colorado's strong wind manufacturing ecosystem was the basis for the establishment of the Wind Technology Area.

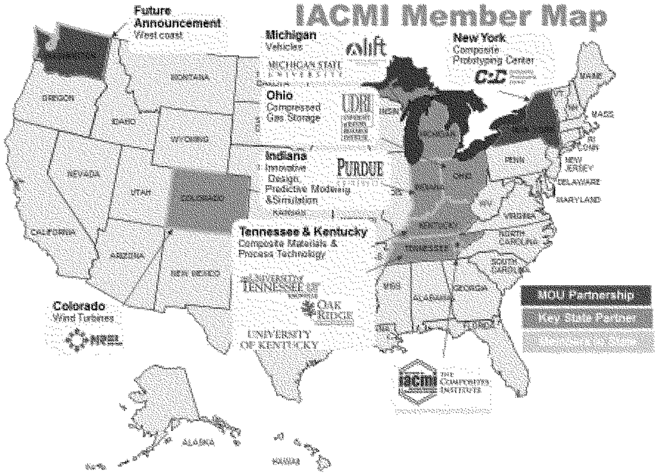
Key partners in IACMI's five technology areas include:

- Vehicles (Michigan)
    - Michigan State University
- Wind Turbines (Colorado)
    - National Renewable Energy Laboratory
    - Colorado School of Mines
    - Colorado State University
- Compressed Gas Storage (Ohio)
    - University of Dayton Research Institute
- Design Modeling & Simulation (Indiana)
    - Purdue University
- Composite Materials & Processes (Tennessee)
    - University of Tennessee
    - Oak Ridge National Laboratory
    - Vanderbilt University
    - University of Kentucky

The institute began just nine months ago, but early successes have been significant:

- The number of organizations committed to **membership has doubled** since the initial funding

- The geographic footprint and capabilities of IACMI have **expanded through partnerships** including:
  - A **co-location announcement with the Lightweight Metals Institute in Michigan.**
  - The recent Memorandum of Understanding signed with the **Composite Prototyping Center in New York,** which expands IACMI's capabilities in the Northeast.
  - An agreement confirmed with the **Composite Recycling Technology Center in Port Angeles, Washington** that will be announced in the very near future.
  - A partnership with an industry association, **ACMA** (American Composites Manufacturers Association), which expands IACMI's presence from 32 states with members to 50 states.

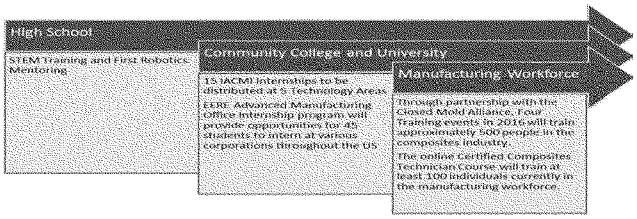


- The announcement and construction of a $50 million facility to advance energy-saving technologies at Purdue University.

- A call for proposals announced within the four months of institute funding.

- A licensing opportunity announced by partner Oak Ridge National Laboratory that will significantly lower carbon fiber production costs and enable commercialization of the innovative technology.

- Workforce development initiatives that include STEM training for high school students, ORAU managed internship opportunities for fifteen college students and at least four workforce training events that will provide training to over 400 composite industry professionals.



STEM Training and First Robotics Mentoring

15 IACMI internships to be distributed at 5 Technology Areas

EERE Advanced Manufacturing Office internship program will provide opportunities for 45 students to intern at various corporations throughout the US

Through partnership with the Closed Mold Alliance, Four Training events in 2016 will train approximately 500 people in the composites industry.

The online Certified Composites Technician Course will train at least 100 individuals currently in the manufacturing workforce.

- Job creation with a specific focus on IACMI's partner states. With technological leadership and diverse membership spanning the supply chain, a new reason has been created for companies to locate jobs and investment in their regions and in the United States.

- Leisure Pools, parent company of Orion Composites and a composite pool manufacturer originally from Australia, has relocated its facilities to Knoxville, Tennessee to be near IACMI as it reinvents itself as a sophisticated producer of a range of carbon fiber and advanced composite materials. It is expected to add 240 jobs almost immediately and up to 1,000 over the next five years.

- In Colorado, Vestas Wind is hiring 400-plus composite technicians in 2016.

- In Indiana, Wabash National Corporation is spending more than $2 million to expand operations for its composites business that will create more than 100 jobs in the next five years.

By coupling basic to applied science, we are expanding potential applications for advanced composites

Advanced fiber-reinforced polymer composites, which combine strong fibers with tough plastics, are lighter and stronger than steel. Advanced composites are used for select purposes now—such as aircraft, military vehicles, satellites and luxury cars— but if they can be produced at a lower cost, these materials could help manufacturers deliver more advanced and affordable products with much broader availability and impact, including:

- Lightweight vehicles with record-breaking fuel economy.
- Lighter and longer wind turbine blades.
- High pressure tanks for natural gas-fueled cars.

Lightweighting is directly tied to energy efficiency. With just a 10-percent weight reduction, fuel efficiency rises by 6-8 percent for internal combustion engine vehicles. For battery-electric vehicles, that 10 percent weight reduction increases vehicular range by 10 percent.

In automotive applications, advanced composites could reduce the weight of a passenger car by 50 percent and improve its fuel efficiency by about 35 percent without compromising performance or safety—helping to save American families thousands of dollars in fuel costs over the car's lifetime.

In the wind energy industry, advances in low-cost composite materials will help manufacturers build longer, lighter, and stronger blades to create more energy. In fact, doubling the length of a turbine blade can quadruple the amount of electricity generated.

OPERATIONS

IACMI's network enables industry-driven R&D along the full spectrum from laboratory to full-scale demonstration, aligned with a technology roadmap for the objectives of the Institute.

IACMI issues call for proposals from its membership to identify and prioritize resources to solve technical challenges that can lead to commercialization opportunities.

IACMI has a variety of mechanisms that aim to maximize options for industry, including short-term projects with industry (known as Technical Collaborations), longer-term collaborative R&D efforts with large potential impacts (Enterprise Projects), and partnerships to address challenges that can benefit the entire composites community (Topic Specific Projects).

There are four levels of membership (Consortium, Resource, Premium and Charter) with increasing levels of involvement and benefits. Consortium memberships are available at $5,000 for small- and medium-sized companies, government and not-for-profit organizations and $10,000 per year for large companies.

IACMI aims to be financial self-sufficient by the end of the Cooperative Agreement with DOE.

IMPACT AND GOALS

As the institute works towards its five/ten year technical goals, it is anticipated there will be other benefits to society and the economy:

1. A 25- to 50 percent reduction in the cost of carbon fiber-reinforced polymer (CFRP).

2. A 50- to 75-percent reduction in CFRP embodied energy.

3. 80/95% composite recycling into useful products

4. Demonstration of materials with energy and cost of glass with carbon fiber composite performance

IACMI projects will result in enhanced energy productivity, reduced lifecycle energy consumption, increased domestic production capacity, job growth and economic development.

The CHAIRMAN. Thank you, Dr. Blue.

Dr. Christodoulou?

STATEMENT OF DR. LEO CHRISTODOULOU, DIRECTOR, ENGINEERING, MATERIALS AND STRUCTURES, THE BOEING COMPANY

Dr. CHRISTODOULOU. Good morning, Chairman Murkowski, Ranking Member Cantwell, Senators, it's my pleasure to be here today to speak to you about advanced materials in manufacturing in the aviation industry.

I am Leo Christodoulou, Director, Engineering, Materials and Structures at The Boeing Company. Today I will touch on three areas that are important in this domain. Energy efficiency, development and use of composite materials, and very important, workforce development.

First, please allow me to give you a short background on The Boeing Company. With approximately 152,000 employees in the United States, Boeing's the world's largest aerospace company. Our operations collectively result in the employment of an additional 1.5 million jobs within the United States.

Let me now return to the first topic. Boeing has a clear strategy and commitment to energy efficiency in the manufacturing processes as well as in operation of our aircraft. Investment opportunities that we have identified within the manufacturing domain include automated fiber placement, a way of making composites out of the autoclave composites, which substantially reduce energy, additive manufacturing, as well as advanced manufacturing and machining and fabrication techniques.

Now, fuel efficiency has been central to the health and vitality of the aviation industry and flight operations have consistently, over the years, become more efficient. For example, today's commercial jets are 70 percent more efficient than the aircraft flying 50 years ago, and we have not stopped. We're moving forward still. Our new 737 Max, which will come into service next year in 2017, will reduce fuel use by an additional 20 percent over the aircraft it replaces. Our new Triple 7X, built in the State of Washington with the new wings, with the first delivery in 2020, will be the most fuel efficient, wide-bodied aircraft of the jet age.

Now let me turn to composites and ceramics. As you know, aluminum structures have been the mainstay in commercial aviation for the last 50 years. However, the double digit improvements in efficiency I spoke of, have really come about by a number of factors including the use of composite materials.

Incorporation of carbon fiber composites in aircraft design improves performance, reduces life cycle energy costs, substantially, reduces the complexity of the parts enabling integral structural improvements for corrosion resistance and damage tolerance. It is a winner all around. For example, carbon fiber composite materials make 50 percent of the 787 Dreamliner aircraft.

Beyond carbon fiber composites we use ceramic made composites and we have evaluated those for use in our aircraft. In 2014, as an example, we flight tested an innovative ceramic matrix composite nozzle which improves efficiency and improves performance of our aircraft.

Finally, I want to touch on one of the most important elements which is the workforce development activities in support of advanced manufacturing.

Advanced manufacturing, especially in the aerospace industry, requires a robust pipeline of students with globally competitive skills. This is a global competition. These skills can be defined not only as STEM, but also as the ability to think critically and solve problems, work in teams and communicate effectively.

This is because today's engineers and assembly line mechanics are likely to work with state-of-the-art equipment, including robotics and advanced materials such as the composites I mentioned on the Boeing Dreamliner.

Boeing is addressing this need in a variety of ways including the development of employer driven education programs. One of these very highly successful programs is the Washington Aerospace Training Research Center which is operated by the Edmonds Community College and Renton Technical College. Senator, you spoke of this.

The Boeing Company works closely with both schools and has identified and created six aerospace industry certifications and provided financial resources and equipment to simulate a realistic work environment. Since 2010, the Center has provided training to more than 3,000 students. That's good.

Again, I would like to thank the Committee for allowing me the opportunity to testify before you today, and I would be very happy to answer your questions.

[The prepared statement of Dr. Christodoulou follows:]

Leo Christodoulou
The Boeing Company
Innovative Technologies in Advanced Manufacturing Hearing
Senate Committee on Energy and Natural Resources
April 12, 2016

Introduction

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee, thank you for this opportunity to speak to the innovative technologies in advanced manufacturing in the aviation industry. I am Leo Christodoulou, Director, Engineering, Materials and Structures at The Boeing Company.

Company Introduction

The Boeing Company is the world's largest aerospace company, the largest U.S. manufacturing exporter and leading manufacturer of commercial jetliners and defense, space and security systems. Boeing has over 152,000 employees in the U.S. In 2015, Boeing paid nearly $50 billion to approximately 15,000 businesses, supporting an additional 1.5 million supplier-related jobs across the country. Our business contributes nearly $1 billion into the U.S. economy each week.

Boeing has a proud history of excellence in aerospace that goes back nearly 100 years. William Boeing first began making twin-float seaplanes in 1915 from a small red boathouse, and while much has changed since then, our company remains unique in that we assemble, test and deliver all of our highly-competitive products right here in the United States. The final assembly facilities for our commercial products are located in the states of Washington and South Carolina, but we have facilities for engineering and manufacturing major components in multiple states beyond those two – including Oregon, Florida, California, Montana and Utah, where we have a growing presence. Our defense and space – related production primarily is located in the states of California, Missouri, Pennsylvania, Texas, Arizona, Florida and Alabama.

Boeing has used technological innovation and a highly skilled workforce to create market-leading products that meet the demands of a diverse and growing global customer base. We evolve constantly to meet our customers' requirements. As an example, in 2014 we launched the 777X with 259 orders and commitments, marking the largest product launch in commercial jetliner history by value. The tremendous market response to the 777X was due to the numerous features that make it 12 percent more fuel efficient than its competitor. They include an all-new composite wing based on the innovative wing developed for the super-efficient 787 Dreamliner, aerodynamic advances such as a hybrid laminar flow control vertical tail and natural laminar flow nacelles, and all-new GE9X engines developed by GE Aviation.

Commitment to Energy Efficiency

Boeing has a clear strategy and commitment to take action to address concerns about energy efficiency in the manufacturing process as well as in the operation of aircraft. Boeing investments within our manufacturing processes include out-of-the-autoclave composites; additive manufacturing that reduces the energy-density of materials; as well as advanced metal machining and fabrication techniques.

Fuel efficiency is central to aviation's business strategy, and the efficiency of aircraft and flight operations have consistently improved throughout our industry's history. This is good for our business, customers, employees and Boeing communities around the world.

The commercial aviation industry has a strong track record of steady technology improvements in reducing aircraft emissions over time. The commercial aviation industry has achieved greater fuel efficiency (and lower emissions) even as it has grown. Today's commercial aircraft are 70 percent more fuel efficient than aircraft flying fifty years ago.

Our airplane family will offer double digit emissions reductions from the airplanes they replace, making them the most fuel efficient fleet in the world. Our new commercial airplanes have been designed to meet and even exceed challenging emission requirements. The 787 Dreamliner family reduces fuel use and CO2 emissions by 20 to 25 percent compared to airplanes it replaces. The new 737 MAX, with first delivery expected in 2017, will reduce fuel use and emissions by 20 percent compared to the original Next-Generation 737. The 777X, with first delivery expected in 2020, will be the world's largest and most fuel-efficient twin-engine jet.

Innovative Technologies

The Evolution of Composites in Commercial Aviation

Aluminum structures have been a mainstay in commercial airplane design for many years. While the evolution of aluminum designs has improved the strength-to-weight ratio, the industry has been seeking double-digit performance improvements in fuel efficiency for new airplanes. Composites, combined with other improvements, have helped provide the path to such improvements.

A composite is a combination of two or more materials (reinforcing elements, fillers, and composite matrix binder) differing in form or composition on a macro scale. The constituents retain their identities: While they act in concert, they do not dissolve or merge completely into one another.

Composites also offer strength-to-weight ratios that enable lighter weight structures that allow the airplane design to feature items such as larger windows and lower altitude pressures in the cabin. In addition, a composite airplane structure has inherent resistance to fatigue damage and corrosion.

Composites are not new to commercial aviation. In fact, composites have been used in airframe structures since the 1950s, and their use has been increasing steadily over the last 45 years. Composite structures on commercial airplanes can be all fiberglass layers, all carbon layers, a mixture of the two (often referred to as hybrid parts), or cured with honeycomb core.

Carbon Fiber in Aviation

Carbon fiber was developed in the 1960s and 1970s for defense aerospace applications, and commercialized in the 1980s. This timeframe from inception; to product development; to implementation is typical for the incorporation of new technologies for aviation applications.

Carbon fibers are reinforcing fibers produced by the pyrolysis of organic precursor fibers such as polyacrylonitrile (PAN), rayon, or pitch. These precursors are transformed through heating and stretching to create carbon fiber, which is then combined with various resins and plastics to create “carbon fiber reinforced polymers” (CFRP). The incorporation of CFRP in aircraft design significantly improves performance, reduces lifecycle fuel consumption, reduces the complexity of the supply chain through integrated structures, and improves corrosion resistance and damage tolerance.

Use of Composites on the Boeing 787 Dreamliner

At Boeing, the use of carbon fiber in our products has resulted in significantly reduced fuel consumption during the lifetime of our airplanes. For example, carbon fiber composite materials make up 50 percent of the Boeing 787 Dreamliner, including the fuselage and wing. In developing the 787, Boeing determined the most effective use of composites by evaluating every element of the airplane’s structure for function, load carrying capability, and durability. This evaluation resulted in composite materials being used extensively on the 787 airframe, making these materials dominant in areas that are traditionally aluminum. Due to its use of toughened carbon materials, solid laminate composite structure is inherently very durable. Tests have shown the 787 fuselage can resist damage that would easily occur in an aluminum fuselage.

Exploring the Future Use of Ceramics in Engines

In 2014, Boeing successfully flight tested an innovative engine nozzle made of ceramic composites designed to reduce noise, weight, and lower fuel use. The ceramic matrix composite (CMC) nozzle went through a series of tests on a 787 Flight Test Airplane, including community noise testing, passing over a large acoustic array in Moses Lake, Washington. Boeing engineers had been working on the technology for over five years prior to the test flight. The program began several years before that with small samples in labs, and resulted in a flight test of the largest built oxide CMC structure in the world, and it performed at a very high level.

Boeing is interested in CMC technology for engine nozzles because it may lead to significant improvements in performance. Modern engines have higher operating temperatures to achieve improved fuel efficiency and reduce emissions. However, these hotter temperatures are pushing the capabilities of current metallic components. CMC technology is lighter than current metallic components and can last longer in the higher temperatures. Special CMC designs are also capable of having acoustic treatments built into them that help make engines quieter, lighter and more efficient. This technology can also enable new, dramatically different engine designs in the future.

Opportunities in Additive Manufacturing

Additive manufacturing (AM) has been defined as "the process of joining materials to make objects from three-dimensional model data, usually layer upon layer." After many years of development, AM has evolved from applications mostly limited to rapid prototyping of polymeric objects to commercial production of both polymeric and metallic components. Early adopters include the aerospace, medical, and automotive industries, which use a variety of different polymers and metals for AM components, the latter of which include steel, aluminum, nickel, and titanium alloys.

Compared to conventional manufacturing (CM) processes such as thermoforming, injection molding, and blow molding (for polymeric components) and casting, forging, machining, and finishing (for metallic components), AM holds at least three promising advantages. First, AM enables designs with novel geometries that would be difficult or impossible to achieve using CM processes, which can improve a component's engineering performance. Second, AM can reduce the "cradle-to-gate" environmental footprints of component manufacturing through avoidance of the tools, dies, and materials scrap associated with CM processes. Third, novel geometries enabled by AM technologies can also lead to performance and environmental benefits in a component's product application. For example, the aircraft industry has adopted a number of different AM components for reducing aircraft mass—including flight deck monitor arms, seat buckles, and various hinges and brackets—which can contribute to greater aircraft fuel efficiency. Boeing is actively working toward utilizing AM for structural aircraft components as well. In addition, we have already used AM for satellite components that have reduced cost and weight by 50% while maintaining performance.

Workforce Development Activities Support Advanced Manufacturing

Future development and implementation of innovative technology relies on a robust workforce with 21st century, globally competitive skills. These skills can be defined not only as STEM (science, technology, engineering, and math) skills, but also as the ability to think critically and solve problems, collaborate well, be creative and communicate effectively.

As a global industrial and technology company, Boeing is constantly competing for highly skilled talent. Advanced manufacturing, especially aerospace manufacturing, requires a robust pipeline of students with 21st century globally competitive skills. This is because today's assembly line mechanics are more and more likely to work with state-of-the-art equipment, including robotics, and advanced materials such as composites as they assemble cutting-edge products like the Boeing Dreamliner. Further, this pipeline is only becoming more critically important as the highly experienced workforces across the advanced manufacturing sector near retirement. Boeing is addressing this current and future need in a variety of innovative and market leading ways, including through the development of employer driven workforce training programs.

Boeing operates a number of highly successful workforce training partnerships in conjunction with regional educational institutions across the country. In an employer driven training partnership, a company like Boeing will work with partner schools to communicate skills needs, assist in curriculum design and program implementation and ultimately hire from the pipeline that is trained by the partner school. This highly effective model ensures students have the skills employers require for in demand jobs. Further, these employer driven training partnerships provide high quality career and technical education not only for future Boeing employees but also for individuals hired by our supplier partners –many of whom are small and medium sized businesses.

One of these highly successful employer driven training programs is the Washington Aerospace Training Resource Center ("WATR Center"). The WATR Center is operated by the Edmonds Community College and the Renton Technical College. The Boeing Company worked closely with both schools to develop curriculum supporting six aerospace industry certifications and provided more than $2.5 million worth of materials and equipment to create a simulated work environment. To date, the WATR Center has provided certificate level training to more than 3,050 students since 2010. Of these students, more than 1,950 applied for a job and more than 1,680 were then hired. Approximately 58% of these students were hired by Boeing and 29% were hired by other aerospace companies, such as our supplier partners.

Boeing has also developed partnerships with school districts to begin providing relevant advanced manufacturing skills education at the high school level, and in some cases enrolling these students in work-based learning programs such as internships before ultimately hiring them upon graduation. These partnerships exist in states such as Oregon, Utah, South Carolina and also in Washington where more than 150 local high school and skill center students were hired last year. In these ways, and others, The Boeing Company is working to ensure a robust pipeline of students with globally competitive 21st century skills.

Closing

We are proud of the position that Boeing holds in the global economy and what our employees all across the country achieve on behalf of the company's research and technology efforts. Again, I thank the Committee for examining these issues and allowing me the opportunity to testify today.

The CHAIRMAN. Thank you, Dr. Christodoulou.

Mr. Ward, welcome.

STATEMENT OF DOUG WARD, DIRECTOR OF SHIPYARD DEVELOPMENT, VIGOR KETCHIKAN

Mr. WARD. Madam Chairman, Committee members, thank you very much for this opportunity to address you today and let you know what we're doing in Ketchikan, Alaska to introduce advanced manufacturing in the middle of the largest intact temperate rainforest in America.

Before I go on I want to introduce myself, Doug Ward. As the Senator said, I've been Director of Shipyard Development for the project in Ketchikan for 22 years now. And to be associated with the project that has reindustrialized the community in a region has been one of the greatest honors that, I think, anyone can be engaged in.

Truly, Ketchikan is a resilient town. I think when I get done at the end of my testimony you'll see why we like to compare ourselves in Ketchikan, in fact, we like to tell people in Alaska, that we are the Boeing of Ketchikan, advanced manufacturing can reach down into small communities and be engaged in by small businesses. And that's what our story is about.

I mentioned the intact temperate rainforest of Southeast Alaska. We probably wouldn't have a shipyard if it were not for the collapse of the timber industry in the 1990's. That timber and fishing has been the backbone of the Southeast Alaska economy for many, many years. And in the 90's it all collapsed. Foreign farmed salmon even hit our fishing industry with a double whammy.

Now in Alaska we have thousands and thousands of miles of coastline, more coastline than all the states combined. As a result, we have a state ferry system with the longest ferry route in the world. And it was with that in mind that enterprised the planners in Ketchikan began thinking about building a shipyard to maintain the state's ferry system back in the 70's.

The state did build that shipyard. It opened in the mid–80's, but for lack of investment and all of the infrastructure required it soon failed. Then along comes the collapse of the timber industry and a few of us in Ketchikan thought maybe that shipyard was a pretty good way to diversify and strengthen, not only Ketchikan and Southeast economy, but add advanced valued added manufacturing to the state.

So I am so pleased to hear my colleagues talk about the importance of workforce. Of all the challenges that we faced in developing, what today is, I believe, one of the best little, small shipyards in all of America, as the challenge of developing a globally competitive workforce, particularly in a population that is non-traditional with respect to advanced manufacturing.

So there were a couple of the challenges that we really had to face up there. One was a non-traditional workforce, and the second was the lack of a talent pipeline. I think those are common not only in Ketchikan but across the nation.

So some of the innovations that we have introduced with our workforce development within the incumbent worker base is developing a multi-skilled approach to training an industrial workforce.

We advance people by the acquisition of having more than one shipbuilding skill, that way they have stable employment and we have a stable employer. I'm sorry, we have a stable workforce.

We're using some very sophisticated production measurement tools that informs us on where in the production process we need to increase our investments in workforce development, where things are going slower, where we need to speed them up.

We also have relationships with our University of Alaska and with our tribal communities too. Just recently the Ilisagvik College from Barrow, which bases its curriculum on the NCCER standard construction curriculum, was in Southeast Alaska and will be opening up a branch of their college in the shipyard, in Ketchikan, providing college credit while people are learning, earning their way toward an apprenticeship program.

On the pipeline, the talent pipeline side, we have partnerships with high schools all around Southeast Alaska, again using standardized curriculum, again with dual credit, the opportunity to get college credit while preparing for work, for work that is year round and full time is a unique opportunity in all of the State of Alaska, particularly in Southeast.

And the last piece is stable funding for workforce investment. We know that the career and technical education fundings are in decline across the nation, particularly in Alaska. I would offer that the national fund for workforce solution is an approach that formulizes a private investment in workforce development leveraging public funds and then has a national fund site that brings in the major national philanthropies to stabilize and work on projects that get people to work. And I think, that's probably one of the most important things that we see in our workforce is a rational workforce investment system.

Now I mentioned our University of Alaska. The University of Alaska, Ketchikan campus is just beginning a $6.6 million renovation of the technical center. They have the state's first maritime career and technical center in the state. So we're looking forward to a long future in advanced manufacturing, and I'll hope to be back someday to report the successes that we're having.

Thank you.

[The prepared statement of Mr. Ward follows:]

VIGOR
ALASKA

Testimony Provided to the US Senate Energy and Natural Resources Committee Regarding Innovative Technologies in Advanced Manufacturing

Tuesday, April 12, 2016

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Madam Chair and Committee Members, thank you for the honor of appearing before you today to talk about innovations in manufacturing at Vigor's Ketchikan Shipyard.

Before I tell you about what we are doing in Ketchikan, a little bit about Vigor.
Vigor is a leading provider of shipbuilding, ship repair and complex fabrication services. With twelve locations and more than 2,500 workers throughout the Pacific Northwest and Alaska, our capabilities range from large vessel construction and repair to high performance military craft and aluminum workboats. We also build quality products for the Hydroelectric, Bridge, Nuclear and Aerospace industries. Our teams share a common goal: providing world-class maritime and industrial services to support our customers and strengthen the communities where we live and work.

Madam Chair, you know, but perhaps not all of your colleagues know, that 9% of Alaska's incoming freight arrives by sea from the lower 48 states and that Alaska's only National Highway System link to the lower 48 states is the aging fleet of Alaska Marine Highway System ferries. Additionally, with salmon being the number one export and fishing being a primary industry in our state, how critical maritime industries are to Alaska. With more shoreline than all of the other states combined and the nation's only Arctic coastline, Alaska is a maritime state.

In terms of the topic of this hearing, I know there will be information provided on new and advanced materials, technologies and techniques. For our contribution to this topic, I want to share specifically about workforce innovations and how that is contributing to something remarkable and crucial in Alaska.

Today, the Ketchikan Shipyard (KSY) is a shining star in the state of Alaska's portfolio of economic development projects. It is a modern, safe, and efficient shipbuilding and repair facility providing year round employment for 200 Alaskans earning family wages in careers in advanced manufacturing. An added bonus is that, in contrast to many Alaskans whose work takes them far away from their families, our employees get to go home to their families every night, a rare condition for many of Alaska's workers.

The KSY is managed and operated through a formal public private partnership between the Alaska Industrial Development and Export Authority (AIDEA), a public corporation and owner of the physical infrastructure; the City and Borough of Ketchikan, providing financial incentives to attract new private investment while the regional economy transitions to the marine industrial support sector; and Vigor, the private sector shipyard operator engaged through an innovative long term operating agreement. A crucial feature and of the Operating Agreement is that rents to AIDEA are made through revenue and profit sharing on Vigor's earnings. All of these revenues flow to a repair and replacement (R&R) fund to assure the KSY is adequately maintained over time. When the R&R account reaches is required minimum level, AIDEA may then return revenue to the community of Ketchikan. Now, with the State facing huge operating deficits generated by the precipitous drop in the price of oil that will likely end revenue sharing with communities from the state's general fund, the value of this feature of the Operating Agreement is becoming apparent.

The beginning of the industrial evolution in Ketchikan began in 1987 when the State of Alaska commissioned the newly constructed KSY to perform maintenance for the Alaska Marine Highway System fleet of ferries, which as I have mentioned, are essential for basic transportation in Alaska. Prior to this date, all maintenance of the state ferry system occurred outside of Alaska. When opened, only a fraction of the planned shipyard infrastructure had been installed and as a result, the yard was closed for several years shortly after opening as two private sector operators failed to earn enough revenue to sustain operations.

By the early 1990s, the forest products industry in Southeast Alaska, then the primary economic sector, began to collapse due to changes in federal forest policy and the State became interested in reactivating the shipyard to not only re-industrialize the Southeast Alaska Region but to provide economic diversity in the state's heavily resource based economy.

In 1994, the State awarded an operating agreement to another Ketchikan contractor and in 1997 the regional forest products industry did collapse creating an economic disaster and triggering receipt of federal economic disaster relief funds. Ketchikan, responding to closure of the Ketchikan Pulp Mill, allocated federal disaster relief funds to create a development plan for the Ketchikan Shipyard and to begin making improvements to the KSY required to establish the facility as viable shipyard enterprise.

Having no prior shipyard operating experience, the new, private sector operator joined with the National Shipbuilding Research Program (NSRP) to meet other shipyard operators and learn about best shipyard practices. The NSRP is a Navy program providing a forum for US shipyard operators to identify competitive weaknesses in the US shipbuilding industrial base, then work collaboratively to make corrections to reduce the cost of building and repairing Navy ships while improving the productivity of US shipyards.

NSRP has technical panels for all major shipbuilding processes including workforce development. Because Alaska's workforce had no experience in advanced manufacturing and because the KSY project was conceived to provide employment for Alaskans, NSRP projects to develop shipbuilding skill standards and model training plans in the late 1990s were both timely and informative for the new KSY operator.

The NSRP Skill Standards were developed through the functional analysis of shipbuilding processes rather than the traditional approach based on occupational titles. This was necessary because job duties for common occupations varied greatly from one US yard to the next. By focusing on the processes of shipbuilding the knowledge, skills, and abilities (KSAs) required to do work are revealed. By understanding what the KSA's or skill standards of shipbuilding are, then common curriculum for upgrading incumbent skills and training new entry level workers can be standardized thereby reducing the cost and time required for training a knowledgeable and skilled US workforce.

Armed with the nation's first set of Skill Standards for the US shipbuilding industry, the NSRP Workforce Panel tackled the question of developing common curriculum. Acknowledging that development of curriculum for skill training is expensive and time consuming; the Panel scanned commercial sources of technical curriculum developed by industry. The Panel soon identified the National Center for Construction and Education Research (NCCER) as a source of industry developed training material for the construction trades. NSRP panelists audited the material and found that for entry level up to mid-skill shipyard production work the curriculum was well suited (a tape measure read the same way in all industry sectors). NCCER has developed rigorous academic standards, testing and performance evaluations that lead to sequential certifications recognized by employers, colleges, school districts and training providers around the world. The US Dept. of Labor has recognized NCCER certificates suitable for use in registered apprenticeships. In the last few years, NCCER has developed training material specifically for US shipbuilders including marine pipefitting, and structural fitter.

In Ketchikan and Alaska, Vigor has developed a Marine Industrial Pre-Apprentice Program based on NCCER training material. High Schools around the Southern Southeast Alaska region are adopting the Pre-Apprentice Program as a way to bridge the school-to-work gap; as the program develops, students will study and take the knowledge tests in the classroom, then go to local participating employers for performance evaluations to gain workplace exposure.

Ilisagvik College, a tribal college located in Barrow, Alaska is working with Vigor to create an extension campus in the Ketchikan Shipyard. Ilisagvik vocational programs lead to NCCER certificates that translate to college credits for an 11 hour endorsement in Crew Leadership and Supervision, then go on to earn an Associate Degree in Construction Technology. Ketchikan Indian Community is partnering with Vigor to provide technical skill instructors in the shipyard for tribal members who will soon be able to earn college credits through Ilisagvik College as they advance their shipbuilding careers at the KSY. The Federal Highway Administration and Alaska Department of Transportation funds

Maritime Career days at the KSY where over 150 high school students travel to Ketchikan by ferry from outlying communities spend a day in the shipyard being exposed to a multitude of career opportunities.

In response to the transition of the regional economy to marine industrial activities, the University of Southeast Alaska – Ketchikan Campus (UAS-K) is just beginning a $6.6 million dollar overhaul of its technical center to create Alaska's first Regional Maritime Technical and Career Center. In consultation with Vigor and other local marine employers UAS-K has developed a 12 week Multi-Skill Marine Worker program that qualifies Alaskans for jobs on Alaska ferries or prepares them to build and repair ships at the KSY and will soon be rolling out an Associate Degree in Marine Transportation.

Vigor's employee advancement program is based on demonstrated acquisition of knowledge and skills in multiple shipbuilding processes. Recognizing that a stable workforce is good for the employee and good for the employer, Vigor provides training opportunities for employees to learn and be certified in skills outside of their core craft. Possessing multiple skills assures continuous, year round employment as demand for various ship production crafts ebb and flow with work that becomes available. To that end we are exploring strategies for a registered apprenticeship in the occupation of Shipbuilding and Repair. By virtue of shipbuilding's demand for a wide range of knowledge, skills, and abilities, the Shipbuilding Apprenticeship will necessarily be a multi-skilled program based on career paths leading to mastery of a primary ship production process followed by acquisition of ancillary or complimentary skills leading to certification as a Master Shipbuilder.

Leadership development at Vigor Alaska is a high priority. As we encourage and train our industrial workforce to become masters in shipbuilding and repair, we also provide aspiring workers the tools to become masters of themselves and leaders in our community. Progressive leadership coaching produces informed and productive people who take pride and ownership in the ships they build and communities they live in.

Successful evolution of the KSY has acted as a catalyst leading to our State's awareness of the Maritime industries as a discreet collection of interdependent activates and companies that, when taken as a whole, represents Alaska's largest private employment sector. In May of 2014 the Alaska Maritime Workforce Development Plan was published identifying high demand occupations and strategies for qualifying Alaskan's for careers in the maritime sector. Whether it is piloting a modern, at sea catcher processor or an engineer aboard an advanced tractor tug driven by cycloidal propulsion systems, or designing and building modern efficient ferries, Alaska's maritime industries are critical to almost every other industry sector in the state.

The Maritime Administration (MarAD) provides two programs that are important to the US shipbuilding industry. First, the Federal Ship Financing Program (commonly referred to as Title X) provides US Government guaranteed debt issued by US or foreign ship owners for the purpose of financing or refinancing either US flag vessels or eligible export vessels constructed, reconstructed or reconditioned in US shipyards and directly to US shipyards for the purpose of financing advanced shipbuilding technology in privately-owned, general shipyard facilities located in the US. The second program is MarAd's Small Shipyard

Grant Program providing grants for capital and related improvements to qualified shipyards that will be effective in fostering efficiency, competitive operations, and quality ship construction, repair, and reconfiguration. This program has been very effective in assisting US Shipyards to acquire modern tooling and equipment and developing capable shipyard workers. The most recent solicitation for this grant program had a strong emphasis on funding workforce development projects to upgrade the knowledge, skills, and abilities of the US shipbuilding workforce. Shipyards across the nation are eagerly awaiting the award announcements for this highly competitive grant program in mid-April.

The recently enacted Workforce Innovation and Opportunity Act (WIOA) of 2014 fosters regional collaboration by aligning workforce development programs with regional economic development strategies to meet the needs of local and regional employers. WIOA improves services to employers and promotes Work-Based Training and contributes to economic growth and business expansion by ensuring the workforce system is job-driven matching employers with skilled individuals.

A maritime workforce investment fund is being formed in Alaska. This fund is based on the National Fund for Workforce Solution's framework that pools private, public and philanthropic dollars to create patient and flexible capital for workforce development practices enabled by WIOA.

The Southeast Alaska Comprehensive Economic Development Strategy, published in February of this year, adopted strategies to expand and improve the Southeast Alaska Marine Industrial Support Sector talent pipeline and incumbent workforces using tools provided by WIOA and the National Fund framework.

Pending legislation that will be of benefit the US Shipbuilding Industry includes the Maritime and Energy Workforce Technical Training Enhancement Act (S 2053). This bill is becoming known as 'Maritime and Energy Centers of Excellence (COE)' and requires the Secretary of Energy to award grants to expand programs in maritime and energy workforce technical training, and for other purposes. The maritime and energy sectors have many crosscutting skills and demand for skilled and qualified workers.

Regional knowledge and awareness of these legislative and commercial tools for creating innovation in workforce and economic development came about through evolution of the Ketchikan Shipyard.

Today, Vigor Ketchikan is building two new ferries for the Alaska Marine Highway System; the first state ferries ever built for Alaska by Alaskans. Our workforce is young in relation to the national shipbuilding work force, but their enthusiasm and passion for innovation, quality, productivity, and safety is inspiring. Through their leadership and determination, Ketchikan is transitioning to be Alaska's marine industrial support center supporting the North Pacific and Arctic Oceans as envisioned by the public and private partners that came together to support development of the Ketchikan Shipyard.

The models of economic and workforce development emerging from Ketchikan are scalable and distributable and are beginning to be adopted in other neighboring communities seeking economic security through advanced manufacturing. As Alaska enters another era of economic uncertainty due to falling oil prices, we provide this testimony today to perhaps serve as guide to other regions and industry sectors desiring a competitive and resilient industrial base based on advanced manufacturing.

Again, I am grateful for the opportunity to share with you our story of the industrial evolution that is unfolding in Ketchikan, Alaska. Where the story is not over, we are confident it will have a successful ending.

The CHAIRMAN. Thank you, Doug.

Dr. Williams, welcome.

STATEMENT OF DR. DAVID WILLIAMS, DEAN OF THE COLLEGE OF ENGINEERING, THE OHIO STATE UNIVERSITY

Dr. WILLIAMS. Chairman Murkowski, Ranking Member Cantwell, members of the Committee, thank you for the opportunity to speak about the transformation innovations occurring in advanced manufacturing at The Ohio State University and at universities nationwide.

I'd like to thank Ohio Senator, Rob Portman, a member of this Committee, for his support and leadership on U.S. innovation. We're fortunate to have Senator Portman and Senator Sherrod Brown representing the Buckeye State in the U.S. Senate.

As the largest industry sector in the State of Ohio, accounting for almost 20 percent of the state's GDP, manufacturing is critical to Ohio's economy. And my testimony today will highlight the strides we're making in Ohio in advanced manufacturing. I hope the examples of research and workforce development I give will demonstrate the ability to leverage public investments in innovation and economic growth, both locally and across the nation.

So let me start with research. A powerful example of Federal research investments supporting manufacturing is the National Network for Manufacturing Innovation, you've already heard about, IACMI, at Oak Ridge.

Ohio State faculty play an integral role in three of the eight current NMMI hubs. I will speak about the one I know best, lightweight innovations for tomorrow, or LIFT, which is based in Detroit.

Ohio State along with Columbus-based EWI and the University of Michigan are the co-founders of LIFT which is a $148 million manufacturing consortium. We're funding multiple projects driven by industry needs that engage some of the world's leading researchers.

Just one of many LIFT projects is a collaboration between Ohio State and GE Aviation in Cincinnati demonstrating that public/private collaboration speeds up the solution process in advanced manufacturing.

This one project designs and tests titanium alloy performances in aircraft engines, tests them in the computer relevant in the lab. Titanium alloys are expensive but they can be thoroughly tested now without cycling them through lengthy trial and error processes in the lab. Such computer-based testing lowers costs, speeds up design and manufacturing time tables bringing new products to market faster and with lower costs.

I want to emphasize that universities themselves also invest in research and Ohio State University's discovery themes we're investing close to $400 million in sudden grant challenges, one of which is materials and manufacturing for sustainability. We're currently hiring 30 new faculty to accelerate advanced materials design and manufacturing. We're building this investment on the Federal Government's materials genome initiative which, as you know, accelerates discovery, manufacturer and deployment of advanced materials in half the time and at a fraction of the cost that it currently takes.

Another example of our own investment is our Institute for Materials Research which has 220 faculty members across seven colleges responsible for implementing the materials and manufacturing for sustainability discovery theme. And just one of many labs within IMR is the Center for Electron Microscopy and Analysis which contains over $30 million of cutting edge electron microscopes used to characterize the next generation of advanced manufacturing materials at the atomic level.

Going out to workforce development, the LIFT education and workforce development team, led by Emily Durrocco, informs national and best practices in advanced manufacturing career pathways. And one example is LIFT Ohio means internships and co-ops. That's an initiative at Ohio State. We have more than 80 internships and many of which co-locate students, faculty and industry partners working together to solve lightweight metal manufacturing problems through a defined statement of work and industry-driven deliverables. This program also taps community college and vocational/technical centers to develop a talent supply chain. So universities are key partners in workforce development.

The College of Engineering has recently established a Department of Engineering Education, led by Professor Monica Cox. This enables student success by developing and delivering state-of-the-art, innovative, multi-disciplinary engineering courses.

In conclusion, let me note that engagement with industry is the hallmark of our land-grant mission at The Ohio State University. Research and development partnerships with major automotive and aerospace companies go back to the 1940's. We strongly believe that collaboration with industry is more important today than ever before and the Federal Government should continue to play an essential role in fostering university/industry partnerships.

Universities are engines of discovery and talent development. Growing and sustaining the innovation ecosystem for advanced manufacturing will require concerted efforts across government, industry and academy such as LIFT and the other NMMIs. Government, universities, and industries working together will ensure that the U.S. remains a beacon of economic prosperity and the undisputed international champion of innovation.

Thank you again for this opportunity. I look forward to answering any questions you might have.

[The prepared statement of Dr. Williams follows:]

TESTIMONY OF DAVID B. WILLIAMS, PH.D., SC.D.
MONTE AHUJA ENDOWED DEAN'S CHAIR
EXECUTIVE DEAN OF THE PROFESSIONAL COLLEGES
DEAN OF THE COLLEGE OF ENGINEERING AT THE OHIO STATE UNIVERSITY
BEFORE THE
U.S. SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

April 12, 2016

Chairwoman Murkowski, Ranking Member Cantwell and members of the Committee, I would like to thank you for the opportunity to speak about the transformational innovations occurring in advanced manufacturing at The Ohio State University and at universities nationwide. At the outset, I would like to thank Ohio Senator Rob Portman, a member of this committee, for his support and leadership on U.S. innovation. Just last week he convened leaders from academia, industry, and regional economic development agencies to discuss transportation and mobility innovation, and its importance to Ohio's and the nation's economy. We are fortunate to have Senator Portman, along with Senator Sherrod Brown, representing the Buckeye state in the United States Senate.

Innovation in the manufacturing sector is vital to maintaining U.S. leadership in the global economy and sparking continued economic growth in states like Ohio, Michigan and others battling back from the Great Recession.

As the largest industry sector in the state of Ohio, accounting for 17% of the state's GDP, manufacturing is critical to Ohio's economy and future growth. The manufacturing sector contributes over $2 trillion to the U.S. economy and supports an estimated 18.5 million jobs, which is about one in six private-sector jobs. Manufacturing also accounts for a substantial amount of our nation's energy consumption. We use 25% of our energy in industrial processes and production, and another 27% to move people and goods.

The advanced manufacturing and materials research occurring at U.S. research universities builds the foundation for the cutting-edge technologies needed to ensure that American companies can efficiently produce goods, while minimizing impact to the environment, natural resource use and energy consumption. U.S. universities, including Ohio State, are global leaders in raw innovation, risk taking, IP production and talent creation. Universities play a catalyzing role in America's manufacturing resurgence, though we would be unable to carry out this critical work without a robust and sustainable investment from the federal government.

My testimony today will highlight the strides we are making in Ohio and across the nation in advanced manufacturing, fueled by public and private investment. I hope these examples of research and workforce development demonstrate the ability to leverage public investments in a commonsense manner to support innovation and economic growth both in our local communities and across the nation.

The National Network for Manufacturing Innovation

A powerful example of federal investment supporting U.S. growth of advanced manufacturing technologies and jobs is the National Network of Manufacturing Innovation, or NNMI. Ohio State faculty play an integral role in three of the eight current NNMI hubs, which bring together the federal government, U.S. industrial partners, venture capitalists, universities, and nonprofits across multiple states. I would like to thank this committee and your colleagues for your ongoing support of the NNMI. Please allow me to speak about the one I know best, the Lightweight Innovations for Tomorrow, or LIFT.

Ohio State, along with Columbus-based EWI and the University of Michigan, are co-founders of LIFT, which is a $148 million high-tech national manufacturing consortium comprised of industry, universities and nonprofits. LIFT, which is based in Detroit and led by Executive Director Lawrence E. Brown, is expected to create 10,000 new jobs in the Midwest over the next five years while driving innovation and growth for a rapidly expanding lightweight materials industry. LIFT has initiated projects that are driven by industry needs and that engage some of the world's leading academic researchers to address those needs. The project selection process is driven by a rigorous planning and prioritization review to ensure that U.S. taxpayer dollars are invested prudently in the most important and broadly applicable industry needs.

One recently announced LIFT project is a joint aerospace collaboration with The Ohio State University and GE Aviation demonstrating the fact that public/private collaboration speeds up the solution process in advanced manufacturing. The GE Aviation-Ohio State project uses computer analytics to design and then to virtually test titanium's performance in aircraft engines in *silico* rather than in *vitro*. The advantage is that titanium, an expensive alloy, can be produced and thoroughly tested without cycling through a lengthy and expensive trial and error process of building, then breaking, a large number of test parts. This computer-based testing lowers cost and speeds up the design and manufacturing timetable, bringing new products to market faster and with lower design costs, thereby improving U.S. competitiveness in a global market. I think you would agree that this is a wise use of public dollars.

Beyond federal investment

As you well know, federal agencies support the bulk of basic or early stage research at U.S. universities and federal labs. You will be pleased to know that while federal funding is vital to our R&D efforts, universities also develop alternative funding streams through our own research investments and through industry partnerships to meet the needs of specific sectors.

For example, Ohio State established the Center for Design and Manufacturing Excellence (CDME) after determining industry needs for a product and process innovation center. CDME provides industry with a simple, expeditious way to access the vast array of intellectual research and physical assets of the university and surrounding research community. Building upon our success in standing up this center with university investment, CDME was awarded $6.8 million from the U.S. Department of Commerce and Department of Defense to foster economic stability and growth in Ohio by advancing the global competitiveness of existing defense and commercial manufacturing companies.

Ohio State professor Glenn Daehn and his research team at the Impulse Manufacturing Laboratory developed several new techniques for joining dissimilar materials by utilizing electrical energy from a capacitor bank. Funding from the U.S. Department of Energy and other federal agencies were used to develop the initial concept. Then, by working with CDME, Professor Daehn's team has been contracted by a commercial entity to design an Ultrafast Capacitor for use in a production manufacturing environment.

We have also directly invested heavily in advanced materials and manufacturing under the University's Discovery Themes initiative – a program that focuses on critical societal needs, reflecting Ohio State's mission as a public, urban, land-grant, research university. Each Discovery Theme includes hiring of faculty who will collaborate with existing resident experts across our departments and colleges to address grand challenges. One such grand challenge is the Materials and Manufacturing for Sustainability theme, in which we are hiring thirty new faculty members to accelerate advanced material design and manufacture. We will build on federal investments in the Materials Genome Initiative, whose goal is to accelerate the discovery, manufacture, and deployment of advanced materials in half the time, and at a fraction of the cost, as we currently do. Ohio State's Materials Innovation Greenhouse initiative will house a rapid prototyping and startup incubator on campus that enables materials scientists and engineers at Ohio State to accelerate the transition of their fundamental research results into the manufacture of new materials and to develop new manufacturing processes for joining of these new materials together into structures and products.

Another example of an institutional investment is our Institute for Materials Research (IMR), which was created in 2006 as a campus-wide, multidisciplinary institute that works with Ohio State colleges and departments to facilitate, promote and coordinate research related to the science and engineering of materials. Led by Professor Steve Ringel, IMR has 222 faculty members at seven colleges who participate. IMR is the gateway to materials-allied research and education at Ohio State; and is responsible for the overall development, coordination and advancement of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme program. IMR Industry Challenge Grants are intended to strengthen new collaborations between university researchers and private industry partners in materials-allied research.

A final example of a critical relationship between the university, federal government and industry comes in the area of corrosion. The annual impact of materials corrosion on the U.S. economy is well into the hundreds of billions of dollars. The State of Ohio, and Ohio State in particular, is the historic home and continues to be a center of excellence in corrosion research. With multi-million dollar/multi-year support from the Department of Defense, a consortium of universities and military academies known as the Technical Corrosion Collaboration (TCC) serves to closely align the research goals of military corrosion experts with those of university scientists, to address fleet sustainability while simultaneously training the next generation of corrosion engineers.

Workforce Development

To fully capitalize on a revitalized manufacturing sector and the large number of high-quality, in demand jobs it will generate, it is imperative that we have a workforce that is well-trained and prepared to fill these jobs. The LIFT Education & Workforce Development team led by Emily DeRocco has developed a federated model that informs national best practices on advanced manufacturing education career pathways. As part of LIFT education and workforce development efforts, the "LIFT Ohio Means Internships & Co-ops 2.5" initiative at Ohio State engages students in real-world work on advanced lightweight metal alloys, manufacturing technologies and design methods that are integral to advanced manufacturing. Out of the 80 internships, 30 are co-located internships involving students, faculty, and industry partners who work together to solve a specific manufacturing issue or project with defined statement of work with industry-driven deliverables. This industry-focused program also taps community college and technical centers and pilot's novel approaches to developing the talent supply chain for manufacturers. These co-op and internship assignments develop a well-trained workforce while exciting students about the career opportunities in 21st century advanced manufacturing.

In Columbus, the Ohio State College of Engineering is nationally recognized for its commitment to undergraduate education. Our teaching methods—including practical, hands-on experience through project-based design courses; a focus on providing undergraduate research experiences; and individualized attention to students—have proven to effectively facilitate students' academic and, ultimately, career success.

Our college has also established the Department of Engineering Education (EED) to strengthen our support of undergraduate education and graduate-level research in engineering education as a growing discipline. The EED, led by Professor Monica Cox, advances the engineering profession and enables student success by developing and delivering state-of-the-art, innovative, multidisciplinary engineering courses and programs such as the First-Year Engineering Program, Multidisciplinary Engineering Capstone projects that focus on industry-driven solutions, and an Engineering Science Minor to broaden STEM exposure and understanding for non-engineering students.

Ohio State has a long history in supporting the materials workforce. Our welding engineering program was established in 1948. Currently we offer the only accredited B.S. Welding Engineering degree in the nation, and also have the only Welding Engineering graduate program, with both masters and PhD degrees offered. Materials joining is a critical enabling technology for manufacturing across a broad spectrum of industries, including the automotive, aerospace, defense, power generation, oil & gas, medical products, electronics, and many others. The economic benefit of new, advanced materials is sometimes often limited or delayed because we first need to figure out how to join them to other materials. Federal investments are directly addressing this challenge. A good example is the National Science Foundation support for the Industry/University

Collaborative Research Center (I/UCRC) known as MA2JIC: Manufacturing and Materials Joining Innovation Center. This center seeks to advance the science and technology of materials joining, with a focus on joining of advanced materials. This center is an outstanding example of a successful public-private partnership; federal funds from NSF provide for center administrative operations, and member companies contribute funds that are pooled to address pre-competitive research and technological advances of interest to them. More than 80% of the center's funds come from its over 40-plus members. It is one of the largest and fastest growing I/UCRCs in the nation.

Conclusion

Engagement with industry is the hallmark of our land-grant mission at The Ohio State University and our College of Engineering. Research and development partnerships with major automotive and aerospace companies date back to the 1940s. Industry's reliance on the engineering talent we produce has existed since Ohio State's birth in 1870.

I strongly believe that collaboration with industry is more important today than ever, and the federal government will continue to play an essential role in seeding the fundamental research and fostering this industry-university partnership. Universities are engines of discovery and talent development, and engines need fuel. Federal funding to support and refine fundamental and applied research is that needed fuel, and it catalyzes the innovation pipeline. Growing and sustaining the innovation ecosystem we envision for advanced manufacturing will require concerted efforts across government, industry, and academia.

Federal support for the advancement of manufacturing research at Ohio State and other research universities around the country has provided the U.S. with the critical resources needed to tackle the biggest challenges facing manufacturing companies. Government, universities, and industry must walk hand in hand to ensure the U.S. continues to be a beacon of economic prosperity and the undisputed champion of innovation.

Thank you, again, for this opportunity and I look forward to answering any questions you may have.

The CHAIRMAN. Thank you, Dr. Williams.

Ms. Wince-Smith, welcome to the Committee.

STATEMENT OF DEBORAH WINCE-SMITH, PRESIDENT AND CEO, COUNCIL ON COMPETITIVENESS

Ms. WINCE-SMITH. Chairman Murkowski, Ranking Member Cantwell and members of the Committee, thank you for the opportunity to appear before you to discuss technologies that could radically transform manufacturing here in the United States.

I have the privilege of representing the now 30-year-old U.S. Council on Competitiveness, a non-partisan leadership organization of CEOs, university presidents, labor leaders and national laboratory directors, committed to advancing U.S. competitiveness in the global economy. Through a deep public/private partnership with the Department of Energy spanning two administrations and through our CEO-led energy in manufacturing competitiveness partnership, the Council is exploring the technology and economic opportunities at the nexus of our 21st century energy and manufacturing transformations.

Indeed, right now, over 50 leaders from our country are meeting at the Council on Competitiveness discussing the cross cutting role of advanced materials in every sector of our manufacturing enterprise.

While recent years have been difficult for U.S. manufacturing, as we transverse a structural transition in the world order of production the winds of competitiveness have begun to blow back in the direction of the United States.

Our 2016 U.S. Council Deloitte survey on global manufacturing competitiveness ranks the U.S. number two now as a manufacturing leader with projections by 2020 that the U.S. will surpass China.

Wages overseas are rising. Labor costs in China have increased fivefold since 2005. And in 2014 alone, manufacturing share of China's GDP declined to 36 percent. The U.S. energy boom has given American producers both the critical cost advantage, created a clear advantage for the U.S. chemical industry and foreign direct investment is flowing into the U.S.

We now must embrace disruptive innovations and accelerate the use of powerful new tools and capabilities to power productivity, growth and job creation. Nano manufacturing, bio manufacturing and digital manufacturing are shaping new products in industries enabled by our nation's long term investments in the digital, genetic and atomic S&T revolutions.

We know the physical world and the digital world are converging through sensors and networks in a data tsunami that's connecting everything on a scale once imaginable through the Internet of everything. We couple this digital infrastructure to the exponential power of our advanced supercomputers to model and simulate complex physical phenomena, manufacturing promises and prophesies and innovators will save time, reduce costs and obtain powerful competitive insights through this shared infrastructure.

Industry experts estimate that investments in smart manufacturing could generate cost savings and productivity gains adding $10 to $15 trillion to global GDP over the next 15 years. Coupling smart manufacturing with entirely new classes of materials and product technologies from flexible electronics to additive fabrication is already empowering innovation and new industrial capacity.

Integral to this energy system transition is the tremendous opportunity to manufacture clean energy products expected to be a trillion-dollar market.

The U.S. enters this new industrial age with significant advantages. We remain the world's epicenter for disruptive innovation. We are still the world's largest investor in R&D, accounting for one-third of all global R&D spending with our Federal investment being absolutely critical.

We have a superb innovation ecosystem where industry, labs, government and universities collaborate, not just on R&D but in large scale, public/private partnerships to reduce risk and accelerate commercialization such as the growing network of national manufacturing institutes and the new energy in materials network underway.

In closing, we stand at the cusp of the new industrial revolution and the stakes are very high. Around the world our competitors are optimizing their industrial ecosystems to be competitive. The U.S. must leverage its strengths in R&D and talent and leverage our strong industrial capacity for productivity and high value innovation.

A final thought. CEOs around the world rank talent-driven innovation as the differentiator for advanced manufacturing competitiveness. We must equip our students with advanced STEM education, problem solving, leadership skills. We must attract and retain global R&D talent and maintain our national R&D investments. And very importantly, we must invest in the training in depth development of an ever up scaled 21st century workforce.

Thank you. I'd be pleased to answer questions.

[The prepared statement of Ms. Wince-Smith follows:]

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Testimony of Deborah L. Wince-Smith, President and CEO
Council on Competitiveness
Before the Committee on Energy and Natural Resources
United States Senate
April 12, 2016

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee, thank you for the opportunity to appear before you today to discuss technologies that could radically transform manufacturing in the United States.

I have the honor and privilege of representing the Council on Competitiveness, a non-partisan leadership organization of corporate CEOs, university presidents, labor leaders, and national laboratory directors committed to advancing U.S. competitiveness in the global economy, and a rising standard of living for all Americans. Analyzing emerging forces transforming the economy and shaping the future, and catalyzing action to leverage them for the benefit of the United States, is one of the Council's most important roles. Today, our "seismograph" is signaling the beginnings of a competitive and technological earthquake.

As we have traversed through a deep transition in the world order of production, with the universe of competitive manufacturing nations ever more crowded, U.S. manufacturing took a severe blow. But, the winds of competitiveness have begun to blow back in the direction of the United States. Wages overseas are rising, for example, labor costs in China have increased five-fold since 2005, and 15-fold since 1995.[1] China's manufacturing activity appears to be slowing down. Its industrial value-add, which grew at 14.9 percent during its peak in 2007, has more than halved to 6.9 percent in 2014.[2] In China, manufacturing's share of GDP has also declined from 41 percent in 2007 to 36 percent in 2014, most of which shifted to services.[3]

Nevertheless, China remains a formidable manufacturing competitor, owing not only to its traditional low-cost value proposition, but also to its development of innovation infrastructure, significant growth in R&D, sheer volume of annual STEM graduates, and a strong focus on technology commercialization.

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[1] EIU, Manufacturing labor costs (US dollars per hour), http://www.eiu.com, accessed in February 2016.

[2] National Bureau of Statistics of China, http://www.stats.gov.cn/english/statisticaldata/AnnualData/), accessed on February 19, 2016

[3] Manufacturing, value added (% of GDP), World Bank (http://data.worldbank.org/indicator/NV.IND.MANF.ZS); Services, etc., value added (% of GDP), World Bank (http://data.worldbank.org/indicator/NV.SRV.TETC.ZS), accessed on February 19, 2016.

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Energy and manufacturing are inextricably linked, and the U.S. shale oil and gas boom has given many American producers, especially our energy industry industries, a critical cost advantage. For example, as reported in our new Council on Competitiveness and Deloitte *2016 Global Manufacturing Competitiveness Index*, on average German manufacturers pay more than twice the cost for natural gas as U.S. producers, and China, India, Japan, and Korean pay about three times as much. And Germany and Japan pay almost three times as much for electricity as U.S. producers do. Natural gas is also a key feedstock for the chemical industry, and lower natural gas prices have created a clear competitive advantage for U.S. chemical producers. Chemical companies globally have begun or are planning new projects in the United States valued at more than $160 billion in new investment, with 61 percent of the announced investments by firms based outside of the United States.[4]

We must build on these positive developments.

The Emerging Transformation of Manufacturing

Today, we stand at a critical juncture, presented with a tremendous opportunity to strengthen U.S. manufacturing competitiveness, with disruptive innovation and powerful new capabilities almost unimaginable a decade ago. We are living in the midst of great revolutions in science and technology. A new age of unprecedented knowledge, unparalleled technological power and inconceivable innovation is unfolding before our eyes, with profound implications for U.S. manufacturing.

Nanotechnology—a new materials, product and process paradigm for manufacturing –is no longer coming of age, it is here, reaching the $1 trillion market milestone.[5] It will shape the future of key industrial sectors such as chemicals, pharmaceuticals, materials, food production and energy.

We are at an inflection point in the commercialization and use of biotechnology. It took 13 years and $3 billion to sequence the first human genome.[6] Today, sequencing a genome takes about 24 hours at cost you could pay for on credit card.[7] These remarkable cost reductions will have profound implications for our pharmaceutical industry. As biomanufacturing emerges, new tools could allow us to engineer biological systems with applications for fuels, medicine, and electronics.

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[4] Shale Gas: $164 Billion and Counting, American Chemistry Council, April 2016.
[5] National Science Foundation and Lux Research.
[6] The Human Genome Project Completion: Frequently Asked Questions, National Human Genome Research Institute.
[7] DNA Sequencing Costs, Data from the NHGRI Genome Sequencing Program, National Human Genome Research Institute.

In the midst of a fundamental energy system transition, we are presented with a "once-in-a-generation" opportunity to capture a large share of the manufacturing and jobs associated with a $300 billion per year set of clean energy markets, expected to grow into the trillions of dollars per year. Fostering greater energy productivity, deployment of renewable energy technologies and deepening clean technology manufacturing investment, while propelling private sector innovation, energy efficiency and competitiveness is at the core of the American Energy and Manufacturing Competitiveness initiative, a partnership between the Council and the U.S. Department of Energy. The AEMC's goals are to:

- Increase U.S. competitiveness in the production of clean energy products by strategically investing in technologies that leverage American competitive advantages and overcome competitive disadvantages.

- Increase U.S. manufacturing competitiveness across the board by increasing energy productivity by strategically investing in technologies and practices to enable U.S. manufacturers to increase their competitiveness through energy efficiency, combined heat and power, and taking advantage of low-cost domestic energy sources.

This multi-year initiative has sponsored a national dialogue across the United States throughout 2013, 2014, and 2015, identifying concrete actions and policy solutions to increase U.S. competitiveness in the production of clean energy products and boosting energy productivity in U.S. manufacturing.

Tangible impacts of this partnership include exciting new programs like the DoE's HPC for Manufacturing initiative that will enable companies to gain access to this key competitiveness driver.

Beyond the Council's partnership with DoE, building upon more than a decade of leadership on energy and manufacturing policy, the Council's Energy and Manufacturing Competitiveness Partnership (EMCP) catalyzes Council research and action around the nexus of energy and manufacturing. The EMCP will capitalize on a distinctly modern breed of energy abundance characterized by new generations of research, talent and technology.

This initiative approaches the country's diverse industrial landscape as a network of distinct but interdependent productive sectors, each with its own challenges and opportunities. To this aim, the EMCP is organized into a series of sector studies hosted around the nation by members of the EMCP Steering Committee. Each sector study dialogue is designed to gather subject matter expertise on key sectors of the U.S. economy and explore the Council's four cross-cutting pillars—

infrastructure, technology, investment and talent. Together, the common challenge and opportunity threads observed across these discrete sectors will be synthesized into tangible policy recommendations for future growth and development in energy and manufacturing.

We are now entering a new stage of the digital revolution. The physical world and the digital world are converging across numerous dimensions through sensors, networks, and a data tsunami. We are connecting things on a scale once unimaginable through the Internet of Things. The stunning potential of these technologies for driving optimization, efficiency, and discovery is an industrial productivity revolution in the making.

For example, the microscope revolutionized biology, medicine, and environmental science, and the telescope revolutionized our understanding of the universe. Imagine giving tools of such profound consequence to every U.S. industry. That is the potential of today's digitally driven data revolution, the illumination of what we have never before been able to see in manufacturing.

In production alone, we will have the ability to illuminate the operation of every machine and device, the cut of every blade, every movement of material, and the consumption of energy minute by minute. Data will provide unprecedented insight for optimizing all aspects of manufacturing, while the Internet of Things will enable unprecedented control of the supply chain. The data tsunami will also transform the way manufacturers approach their markets, manage their organizations, deploy their people, conduct their R&D, interact with the supply chain, and more. In an era where great opportunities center around creating value from data, the ability to manage big data—to perform modeling, simulation, and analysis—will determine the products, industrial processes, and business models of the future.

But the value of the insight created by this convergence will extend across the manufacturing value chain, leveraged by numerous actors such as equipment and machinery suppliers, service providers, economists, insurers, and investors.

Industry experts estimate that investments in smart manufacturing could generate cost savings and productivity gains that could add $10-15 trillion to global GDP over the next 15 years; that is an enormous value, equivalent to about the size of the U.S. economy today.[8] The CEOs surveyed for our *Index* ranked cost competitiveness and productivity as the second and third top drivers of manufacturing competitiveness, and key to boosting profits in an era of sluggish economic growth.

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[8] Evans, P.C. and M Annunziata, "Industrial Internet: Pushing the Boundaries of Minds and Machines." General Electric Company, Fairfield, CT, 2012.

Couple smart manufacturing with entirely new classes of product technologies—from flexible electronics to the vast applications for technical fibers and textiles—and you see incredible opportunities for innovation and new industrial capacity.

Not surprising, the U.S. CEOs surveyed for our new *Index* ranked predictive analytics; smart, connected products; and smart factories as #1, #2, and #4, respectively, in terms of future importance to manufacturing competitiveness. As manufacturing industries increasingly apply more advanced and sophisticated product and process technologies, the traditional manufacturing powerhouses of the 20th century—including the United States—are back toward the very top of the 10 most competitive nations in 2016, according to our new *Global Manufacturing Competitiveness Index* analysis.

There is even more potential. The Internet disrupted and democratized publishing, broadcasting, and communications, and hundreds of millions of new participants poured in with podcasts, blogs, YouTube videos, and web pages. What happened in the world of bits in cyberspace is now happening in the world of atoms, in digitally enabled push-button manufacturing.[9]

The tools of production are now available to individuals, disruptive technologies—$1,000 3D printers, prototyping tools, laser cutters, easy-to-use design software, off-the-shelf electronics, and desktop machine tools. These are changing the economics of production, who can be a manufacturer or creator, and putting the power of production into the hands of the masses.

Barriers to entry are falling. An individual innovator can design and make a product without owning any manufacturing infrastructure—no warehouse, no assembly line, no forklifts, no heavy equipment, no inventory. Things can be made through micro-factories, Kinko's-like Tech Shops, or using small production contracts. It used to take cumbersome bank transfers, letters of credit, and purchase orders to engage an assembly line in China. Now you can do it with a text message, an email, a credit card, or Pay Pal account. It is becoming possible for someone to imagine, develop and scale a disruptive technology independent of traditional institutions of innovation and production.

Enabled by these new technologies, a "Maker Movement" is growing across the country, a huge opportunity for the United States to gain competitive advantage by expanding and empowering our pool of creators, innovators, and entrepreneurs.

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[9] In the Next Industrial Revolution, Atoms are the New Bits, Wired, January 25, 2010.

The policy community needs to better understand this new, democratized manufacturing landscape, and devise ways to support the creativity and innovative capabilities of independent innovators who numbers could be significant. In this regard, I commend the OSTP/OMB FY 2017 science and technology budget guidance for encouraging Federal agencies to use approaches to foster collaboration with members of the Maker Movement.

The United States Has Significant Manufacturing Competitiveness Advantages

As we enter this new age, the United States has significant competitive advantages, according to global CEOs:

- We remain the world's epicenter for disruptive innovation, thanks to our exceptional research infrastructure, and low barriers to entrepreneurs and start-ups.

- We are, by far, the world's largest investor in R&D, accounting for one-third of global R&D spending. Spending more than $450 billion per year, the United States invests more than $100 billion more than the EU and more than $100 billion more than China, building up a globally unparalleled national stock of science and technology. The recent policy change to make the R&D tax credit permanent will foster increased levels of investment in advanced technologies and innovation.

- We have unique assets such as our national laboratory system and top research universities, pioneers in basic research and breakthrough technologies.

- We have a superb innovation ecosystem where industry, start-ups, labs, and universities collaborate on R&D to enhance manufacturing competitiveness, with new opportunities emerging in initiatives such as the National Network of Manufacturing Innovation Institutes.

- We stand at the top in terms of patents filed, 29 percent of patents filed by all countries in 2014.

- We have a vast amount of venture capital pouring in to commercialize advanced technologies.

These are key assets for establishing the future of our global advanced manufacturing potential.

Government Policies Matter to Manufacturing

Governments around the world are becoming increasingly aware of the significant benefits an advanced manufacturing industry provides to national economic prosperity. Likewise, manufacturing companies are keenly aware of the role government policy can play in their success. Therefore, many nations with unfavorable or overly bureaucratic manufacturing policies are working to improve and reform them, invest in greater economic development, and strengthen overall manufacturing infrastructure, while seeking to partner in more productive ways with businesses.

U.S. CEOs surveyed for the *Manufacturing Competitiveness Index* believe the United States has favorable policies around key elements of manufacturing, centered around sustainability, technology transfer, monetary control, science and innovation, foreign direct investment, and intellectual property protection.

However, U.S. corporate tax rates and taxation of foreign earnings are seen as disadvantages for manufacturing in the United States. Our corporate tax rate is the highest in the developed world, high compared to our major manufacturing competitors, which discourages investments from multinationals and foreign sources. The 39.5 percent corporate tax rate in the United States compares to 33 percent in Japan and Germany, 25 percent in China, and 24.5 percent in South Korea.

Also, we have repeatedly and consistently heard from executives their concern about the high cost, complexity, and uncertainty in the current U.S. regulatory environment. More than 2,000 manufacturing-related regulations have been enacted since 1981 in the United States—an average rate of more than 70 per year—according to a study by The Aspen Institute. Further, the research indicates that a dramatic increase in the number of regulations has resulted in higher compliance costs, which have grown at a sharper rate than inflation-adjusted GDP and manufacturing output.

Talent: The #1 Driver of Manufacturing Competitiveness

Finally, I want to emphasize the importance of America's creative, innovative, industrious, and productive workforce. Once again, the global CEOs surveyed for the Council's *Manufacturing Competitiveness Index* cited talent—defined as the quality and availability of highly skilled workers which facilitate a shift towards innovation and advanced manufacturing—as the most important driver of a country's ability to compete on the global stage. Over the past three of our manufacturing index studies, talent has been the most important driver of global manufacturing competitiveness, demonstrating the strong influence a highly skilled workforce can have on a nation's overall competitiveness.

Technology-intensive sectors dominate the global manufacturing landscape in most advanced economies and appear to offer a strong path to achieve or sustain manufacturing competitiveness. And these industries require high skills. As shown in an analysis included in the Council's new report *WORK: Thriving in a Turbulent, Technological and Transformed Global Economy*, U.S. technology-intensive, globally competitive manufacturing industries have higher than average skill requirements. For example, the share of jobs typically requiring an associates degree or higher is 48 percent in both the pharmaceutical industry, and the aircraft and aerospace industry, and 58 percent in computers and electronics manufacturing. This compares to 20 percent in manufacturing generally, and 26 percent in the economy overall.

Education infrastructure is a foundational requirement for the development of talent. In today's borderless economy, nations compete by being global leaders in attracting, developing, and retaining top science and engineering talent to drive world-class innovation and R&D. This demands an education system that arms students with advanced STEM skills, creative problem solving skills, entrepreneurial training, and leadership skills. A nation's key to greater manufacturing competitiveness lies in a workforce equipped with the science and math backgrounds to compete with the best, and the creativity, business acumen, and leadership to be pace setters for the world. The CEOs surveyed see developed nations—including the United States—as the most competitive in terms of talent. But, as executives around the world rank talent as the most important driver of competitiveness, the competition for talent among nations and companies is expected to be fierce.

In closing, in this age of interplay between bits and atoms, we stand at the cusp of a fourth industrial revolution. The stakes, for countries and companies to successfully navigate this transition, are high. Our competitors also recognize this transformation. For example, the German government launched the "Industry 4.0" initiative that will bring together its capabilities in artificial intelligence, machine learning, sensors, advanced robotics, and automation with the intention to push Germany into a new industrial revolution.

As the new battleground for global competitiveness takes shape, the United States must leverage its foundational strengths in R&D, talent, and strong industrial ecosystems, and compete with high value innovation and high productivity underpinned by data and the emerging array of advanced manufacturing technologies. Thank you.

The CHAIRMAN. Thank you, and thank you to all of the panelists who have joined us here this morning.

Mr. Ward, let me ask you a question. I just had to smile, as did my colleague from Michigan, when you said that Ketchikan is the Boeing of Ketchikan or the shipyard is the Boeing of Ketchikan. We liked that reference. Having been at the shipyard there on many, many occasions, I know that you take exceptional pride in developing that local talent to ensure that the jobs that are there are jobs that can support families in Ketchikan, and I think the efforts have been exceptional.

If you were to have told people in the Ketchikan area that, in our little shipyard, we would be taking on building the Alaska class ferry project, if you had made this statement some 20 years ago, they would have said that is pie in the sky. We cannot build ships like that. That all happens down South.

We have changed that dynamic because of a commitment but, I think, also a commitment from those to make sure that the jobs that are created, the training that goes on, allows you to do just that.

Can you speak real quickly to where you are with the Alaska class ferries project and the significance of something like that, because it truly is a game changer?

Mr. WARD. Yes, thank you very much, Senator.

The shipyard itself started out in the early mid-1990's when we opened it up as a repair station for the Alaska main highway system fleet. As the economy collapsed we were asked to develop a plan for development of the shipyard, and it dawned on us that ship building, unlike ship repair, is a little bit of a different activity.

Ship repair is very uncertain. You never know what you are going to find when you begin opening and inspecting systems on a ship, compared to ship building where you have a complete set of plans drawn out in detail and you have time to develop a build strategy and put that plan into effect. It's much more organized than ship repair. It is also a more year round activity. So we felt that ship building was very important to have in Ketchikan to provide year round employment so that we could maintain a skilled workforce.

But I think we ought to, as we look forward, some of our first new builds were local/state ferries that take us back and forth to our airport bridge. So we gradually stepped into it. And I guess the fact that we're finally building Alaska State ferries with 200 Alaskans that are trained to global standards in ship building is a real testament to the persistence of the citizens of Ketchikan and the ability of our nation to develop training resources and techniques that are affordable and accessible to small businesses around the nation.

So where 20 years ago, yes, the answer to that question would have been astonishment and skepticism, with what we've learned through things like the National Shipbuilding Research Program and participating on the Council on Competitiveness to understand how to develop a global workforce, not only is it possible but we're actually doing it.

So we're about 25 percent through a two ship construction project. We're about a year and a half into it, and the first of the ships will be delivered in 2018. That supports about 90 jobs a year for four years in a community where year round employment is a real rarity.

I'd also note, we're probably one of the few shipyards in the nation that has its own totem pole at the front gate. We do that to honor the cultures that have been plying the waters around Ketchikan for thousands and thousands of years.

The CHAIRMAN. That is a great success story. I appreciate that, thank you.

Let me turn to my Ranking Member, Senator Cantwell.

Senator CANTWELL. Thank you, Madam Chairman.

Dr. Christodoulou, you mentioned the Triple 7X, and we're so proud of that. That represents a pretty significant milestone in advanced manufacturing, because you are bringing the wing development back to the U.S.

Dr. CHRISTODOULOU. Yes.

Senator CANTWELL. So what about that gave us the edge in either manufacturing? How does our continued innovation keep us ahead in that?

Dr. CHRISTODOULOU. Yes. Boeing has invested $1 billion in the new Wing Center which will sustain jobs in Puget Sound. I have our fact sheet for the record.

[The information referred to follows:]

Boeing Celebrates Grand Opening of 777X Composite Wing Center

Investment of more than $1 billion sustains thousands of Puget Sound jobs

EVERETT, Wash., May 20, 2016 /PRNewswire/ -- Boeing (NYSE: BA) employees today joined with community leaders from across the region to celebrate the grand opening of its new 777X Composite Wing Center (CWC) in Everett, Wash.

The facility, located on the north side of the main final assembly building, will manufacture the world's largest composite wings for the 777X, the company's newest commercial jetliner, and sustain thousands of Puget Sound area jobs.

Boeing has invested more than $1 billion in the Everett site for construction and outfitting of the new building.

"Today's event is bigger than celebrating the opening of a magnificent new building," said Boeing Commercial Airplanes President and CEO Ray Conner. "It's about our employees, and shared success with our partners around the region and in Olympia in keeping the Puget Sound at the forefront of aerospace leadership for decades to come."

Construction of the new CWC building required approximately 4.2 million hours of construction time. At its peak, 1,700 contract employees worked on the project. By the numbers, the new building required:

- 31,000 tons of steel with the highest beams weighing 720 pounds (326.587 kilograms) per foot.
- 480 miles of electrical cable.
- 80,000 linear feet of process piping.
- 170,000 cubic yards of concrete were poured. The concrete was brought to the site by more than 16,500 truckload deliveries.
- The CWC is more than 27 acres under one roof – the equivalent to 24 football fields.
- The building will contain three of the world's largest autoclaves – each big enough to fit two Boeing 737 fuselages inside.

The 777X advances the world's most efficient twin-aisle family of airplanes. Two models will comprise the 777X family – the 777-8X, with approximately 350 seats and a range capability of more than 9,300 nautical miles; and the 777-9X, with approximately 400 seats and a range of more than 8,200 nautical miles.

The 777-8X competes directly with the Airbus A350-1000, while the 777-9X is in a class by itself, serving a market segment that no other airplane can. To date, the 777X has accumulated 320 orders and commitments from six customers worldwide. Production of the 777X is scheduled to begin in 2017, with first delivery targeted in 2020. A fast motion video of the CWC construction is available for download here: http://bit.ly/23YQxqK

Thank you, Senator Cantwell, for that question.

We are very excited about the fact that we are, indeed, building the new factory in Seattle—and of course the wings.

The innovations are based on our ability to form the largest wing composite structure ever made in the State of Washington here with the best technology that we have today which is beyond what we currently use for the 787. We have a very innovative design. And the composite fabrication processes for these very large wings take into account, not only advanced materials, but modeling and simulation of this very large structures which, if I may just share with you how composite structures is made?

Where you have this layer by layer. It's a form of additive manufacturing. It's a layer by layer tape which is placed on the composite material, on the uncured composite material. And that green state material, as we call it, goes into the autoclave to form the final ultra strong, ultra lightweight shape. The technologies for doing that involve not only good modeling and simulation of the distortions that make a rise as a result of the processes so that we minimize them, but they require instrumentation and tooling of the high precision to place the fibers and to control the temperatures accurately.

That type of technology and that infrastructure expands beyond Boeing with a lot of our local industry and other companies in the area that actually produce that equipment.

So in building the wings in the United States, not only do we have a much better product, higher performance product of the largest of their kind, but we have also increased the whole ecosystem of advanced manufacturing in composite structures. State of the art, best in the world, very competitive and we look forward to a very productive and successful program there.

Senator CANTWELL. So you could say this is an example of advanced manufacturing investment bringing jobs back from overseas?

Dr. CHRISTODOULOU. Absolutely. Absolutely.

A significant number of jobs, high quality jobs and fulfilling careers, not just jobs, but fulfilling careers for our people. I think that that makes a very strong element in our ecosystem of manufacturing.

Senator CANTWELL. That brings up my follow up question to you and Mr. Ward, which is, whether it is shipbuilding or aerospace, we need more skilled workers. How do we go about getting, accelerating the skill level of our workforce?

Dr. CHRISTODOULOU. Yeah, I think that's one of the biggest challenges that we face as a nation, not only because of the changing nature of the jobs, of the careers that are coming along, but because of the retirement of a lot of our people that are coming up and the changing of the workforce.

And if I may, I'd like to think of it this way. Boeing will celebrate its 100th year anniversary coming up in July, but the technology of the last century was subtractive manufacturing, you know, sort of machining of large parts. The technology of the new century is additive manufacturing. It's the opposite.

In that transition we need to train our people in the new skills of the new century. If they're information-based, they're data driven and they work collaboratively with robotics, not the robotics to replace our people, but for the robots to do the repetitive, dangerous and dull jobs and allow our people to use their creativity and problem solving, that's a very important part of the complete ecosystem for training as we look forward.

We need to work collaboratively with those robots so they can do the dirty jobs and we can do, our people, can do the innovation and interesting jobs and the fulfilling careers.

Senator CANTWELL. Mr. Ward?

Mr. WARD. Thank you.

Yes, there's several approaches we're taking to accelerate development of a globally competitive workforce in Ketchikan.

One of them was developed by the War Manpower Commission in 1942, a methodology of learning called training within industry that was used to teach Rosie how to rivet. And I think you might remember the outcome of that. The weapons that Rosie developed helped manufacture two heavily industrialized nations on two fronts in a very short period of time.

But that, and the Doctor spoke to a workforce that has more than just the skills but has the awareness and the leadership capable to not only become master shipbuilders but masters of themselves as individuals and most importantly, leaders in their community.

We have a young man in our workforce about 26 years old, who recently ran new to Ketchikan, ran for our rural assembly and won, surprised everybody. And he did it through technology, through social media.

Another approach we take, and it has to do with how people learn and the resources available and it has to do with cell phones, most information in shipyards in the United States come from the top/down to the shop floor. And if any changes need to be done to the plans or anything, that goes through an arduous process back up through the chain of command from project management out to the project engineers and can take weeks, days and days, if not weeks and months to affect changes to the design of a ship.

So a young fellow from Lawson Associates, whose office of naval engineers is in Seattle, who is the engineer for our ferry project came up with a quick app that he calls Redlining. And now with the Redline app our folks on the shop floor, men and women, when they see an exception to the design that needs changing, that needs a markup, or things aren't fitting together, they can take out their iPhone, take a picture of it or take a video of it, speak into the microphone, explain what the problem is, and hit send. That goes out to the production team all the way up to management as well as down to Seattle to the Glosten offices where those changes are made.

So and again, those ideas are coming, not from management, but they're coming from the shop floor, from the front line workers.

Senator CANTWELL. Thank you, Mr. Ward.

Sorry to go over. Thank you, Madam Chair.

The CHAIRMAN. Thank you.

Senator Lee?

Senator LEE. Thank you, Madam Chair.

Thanks to all of you for being here today to discuss these interesting issues.

We have heard a lot of fascinating discussions about how new technologies are functioning and what the government and private sector are doing to facilitate research and encourage innovation. It brings about a lot of these developments that make our daily lives better.

Our economy is, of course, changing dramatically as a result. Jobs that have supported families for years, for decades, for generations, for centuries, in some ways, no longer exist due to automation, globalization and other related trends, many of which lie well beyond and outside the scope of public policy.

Research from the World Economic Forum found that over 5,000,000 global jobs could be lost by 2020 as a result of advances in genetics, artificial intelligence, robotics and other technological advances. The research also predicts that 2,000,000 new jobs will be created and that 65 percent of future jobs will be careers that have not yet been invented, that do not yet exist.

Given these challenges and also these opportunities, I want to make sure that Americans are prepared to thrive in this new economy and to participate in the job markets of the future. Those that we cannot fully anticipate now but that we should be looking toward in an effort to understand before they hit us.

But to be candid, I am worried that our current institutions may be failing in some ways to help us prepare American workers for the jobs that might be available for them tomorrow. For instance, Federal higher education policy today tends, somewhat, to marginalize vocational and parochial training in favor the more traditional four year colleges. I believe this imbalance is not only unfair, it is economically misguided. Just as a matter of economic strategy, it is not a good idea.

If the government is going to assist young people to attend college and to read Shakespeare, I think it should also provide assistance to students of all ages, who want to attend technical school to build and repair ships, for example.

Now none of this is to denigrate or marginalize in any way the value of studying Shakespeare, but I think that is a great thing. We ought not be providing the one and not the other, especially when we see that advances in technology are changing the workplace.

So Mr. Ward, I would like to ask you a question. How has the shipping industry changed since you entered it, and as a follow up question to that, I would like to know whether you think that the current education system is meeting the needs of the modern worker?

Mr. WARD. Well thank you, Senator.

Well there's been enormous changes in the shipbuilding industry since we started just 20 years ago, and those changes have to do with the speed with which information is transferred from one location to the other. And I think with the distribution of electronic media throughout the workplace, the ability to have information flowing, not only to the workshop floor but from the shop floor back to the design teams is an enormous innovation and ability to speed up the production process.

The question about our workforce development system, I've been on our Workforce Investment Board of the State of Alaska for nearly 20 years, been the chair for three or four years. And it is my opinion that we need really to overhaul our investment system and education system to honor the production skills that go on in advanced manufacturing. It is no longer a dirty, grubby job. Almost every production phase in the shipyard has become so technically advanced that it takes a minimum of the equivalent of two-year associate degree to become a productive entry level worker.

I think that's how the industry changes a lot. Our demands for technical knowledge on the shop floor has certainly increased. And I think those of us that have respect for the front line worker and begin to treat the front line worker as a fixed asset with a 30-year life span and if we, as a society, can provide the educational tools and training tools for them to take advantage of the technology that we have available, that we will be back, certainly in the shipbuilding world, as competitive as any nation in the world.

Senator LEE. So there is a lot at stake if we do not reform it. If we do not do that we could stand to lose it.

Mr. WARD. Absolutely.

Senator LEE. Okay.

Thank you, sir. Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Lee.

Senator Franken?

Senator FRANKEN. What an exciting panel.

You know, sometimes in this job we get a little pessimistic when we see things. This is unbelievable what you guys are doing, and this makes me an optimist.

Because of the amazing things that we are doing in advanced manufacturing, Ms. Wince-Smith talking about the future, all of you talking about the future. There are a couple things I want to talk about.

Skills gap, which we have been talking about. I have a thing called the Community College to Career Fund Act. Basically what it does is it says it puts money into exactly what we are talking about, training workers, because manufacturing is not dark, dirty and dangerous. It is saying that yes, go to a community and technical college while you are working so you can get credit. Right? Is that what you are doing in Ketchikan?

Mr. WARD. Yes, sir.

Senator FRANKEN. Could somebody talk about this some more? We need apprenticeships. We need to do what they are doing, what they have been doing in Germany and Switzerland. And we can do this. Yes, baby boomers are retiring from these jobs.

But boy, we have people who need jobs and need high-skilled jobs. And these jobs, yes, automation is not, should not be replacing people. It should be creating the opportunity to place people to have higher skilled jobs.

Can someone talk to that? Not for too long. [Laughter.]

Dr. CHRISTODOULOU. I'll be glad to. Thank you, Senator.

I feel passionate, in the same way that you do, about the skills that are required for the new jobs.

For example, we need the new jobs for the people that develop the robotics, that program the robots. It's a different skill set than we had, than we needed in the past, and I think that is a tremendous opportunity for our young people. And the community colleges also provide training and retraining of our existing workers. We must not forget them.

Senator FRANKEN. Right.

The idea that you are going to go to college for four years and then never go to college again is silly.

What we are talking about is you get a credential. You go to work, and your employer will send you back to school while you are working, while you are earning money, and pay for your college and that goes to college affordability.

Dr. CHRISTODOULOU. Exactly.

And you know, employer programs such as ours that have spent over a billion dollars since 1998 in training our own workers at colleges throughout the country are really important, I think, and need to be emulated because you know, the rate of change in technology is so fast, a degree that you, that we, obtained 20 years or 30 years ago may not be relevant anymore. We need new skills.

Senator FRANKEN. Right. So you are going to go back and forth to school?

Dr. CHRISTODOULOU. Exactly.

Senator FRANKEN. Or get your skills while you are working.

Dr. CHRISTODOULOU. While you are working.

Senator FRANKEN. Okay.

Dr. CHRISTODOULOU. In the Employee Training Program.

Senator FRANKEN. So, wonderful stuff there.

I want to talk about energy efficiency. I grew up in Sputnik. And Sputnik, our response to Sputnik was holy mackerel, the Russians/Soviets are now ahead of us in space and have nuclear weapons. We are frightened to death.

My parents sat me and my brother down in our living room in St. Louis Park, Minnesota, and he said, “you boys are going to study math and science so we can beat the Soviets.” I thought that was a lot of pressure to put on a six-year-old. [Laughter.] But my brother and I studied math and science, and we beat the Soviets. So you are welcome, everybody. [Laughter.] You are very welcome. You are very welcome.

Last December, 195 nations got together and said that we are going to reduce greenhouse emissions. I want to know how, what we can do as a nation, to make a reality of responding to this crisis, this “Sputnik” moment, to create the next generation of clean energy technologies that are manufactured in America? Ms. Wince-Smith?

Ms. WINCE-SMITH. Thank you, Senator.

I just have to jump in and say that they were the four Ds Japanese said back in the 1990’s, dirty, dumb, dangerous and disappearing. And so we know the last one is no longer the case on manufacturing.

You know, you mentioned energy efficiency and energy productivity is really emerging as one of the competitive edges in moving in to this clean energy supply chain because even these new materials we’re talking about, the properties they’re delivering are so much more, not just efficient but productive in how energy is generated and used.

I think in the case of the United States what we're seeing is in addition to the concern about climate and all of that impacting our environment, is a real business case for moving out on the energy front. And it's not just nice to be doing anymore. It is absolutely critical to their competitiveness and competitive advantage.

An example, I think, of this very, very exciting on energy productivity efficiency now is in the textile industry. We were talking about the revitalization of shipbuilding, but, our textile industry is really on the move. For example, we have at the Council on Competitiveness, we're very proud of this, the first installation of new carpet made by Mohawk in South Carolina, totally sustainable, completely manufactured, designed here with a very modern factory. I just learned a week ago that they take all of the bottles from Pepsi and use those and recycle those to produce this carpet, and they're saving huge amounts of energy. So they see themselves now as being on the forefront also as both an energy producer, user and moving end of the clean manufacturing space.

I think that the United States is really poised to capture many of these markets, but it's going to depend on a whole set of issues that we've been talking about here today.

Senator CANTWELL [presiding]: Thank you.

Senator Stabenow?

Senator STABENOW. Thank you very much, Ranking Member and to our Chair, this really is a terrific hearing on a subject that many of us are very excited about in a number of ways.

Coming from Michigan, obviously I have a passion for manufacturing and as it is changing the opportunities we have. Personally I do not believe we have an economy unless somebody makes something and grows something. And frankly, we do not have a middle class unless somebody makes something and grows something. In both of those areas technology is causing change and there is innovation but there are incredible opportunities.

So let me start with one piece that all of you have talked about which is on the research end of things which again, to keep us ahead of everyone else, the ability to put together the composites, to be able to deal with all of the different issues that we need to deal with.

Dr. Williams, I have to say while Ohio State is a great competitor of Michigan State and the University of Michigan on the basketball and football fields and others, we are proud to be partners with Ohio State as we are looking at how we develop these new materials, new processes which is really where we are going to need to be as we are dealing with energy efficiency as well as other opportunities.

In the Energy bill that I am hopeful is going to be able to be passed by the Senate and the House and signed into law, we have a Vehicle Innovation Act extension which is very important around the ability to partner the Federal Government doing research and development in all of these areas, a very important role, I believe, for the Federal Government.

The question that I have for anyone that would like to respond to it is, what are the biggest challenges to getting these technologies into the marketplace? We see the partnerships going on around research. It is incredibly important that the Federal Government, I believe, invest in that as well as the private sector. We have these new ideas. How do we get them into the marketplace, and what do you think the Federal Government's role is in moving this from basic research actually into the marketplace?

Yes, Ms. Wince-Smith?

Ms. WINCE-SMITH. Thank you, Senator.

I'll start on a couple issues. One, while we have a very strong dynamic venture capital system in the United States, so much work is underway that we do have this gap but it's time to scale up.

Senator STABENOW. Right.

Ms. WINCE-SMITH. You know, new innovative companies, and that is a huge challenge.

The venture capital business model really doesn't work for that. When it's time to actually put the resources in.

Senator STABENOW. Right.

Ms. WINCE-SMITH. To build a factory and to go at scale. And so, how we develop partnerships between some of these smaller innovative companies and our large scale enterprises that are the end users of some of these things, is very much an opportunity and a need going forward.

The other thing I would say that is an advantage to the United States is our strong intellectual property laws and the fact that we're not dealing with some of those negative issues that are in other parts of the world. Accelerating that for partnerships is very important as well.

Finally, a good example I would mention is on the research and development and getting things into the market. Probably one of the biggest barriers now we're facing is entrenched infrastructure where a disruptive technology or product really impacts the whole life cycle of that activity. I'll give you an example. We now have nano coatings, coatings in materials made at the nano level.

Senator STABENOW. Right.

Ms. WINCE-SMITH. And that's a huge multi-trillion-dollar market. A lot of the innovations coming from our universities, our labs and the existing players in big industry don't always see those as in their interest to adapt.

The other piece is we don't have the standards and the certification yet for some of these. I think that's an area where we need deeper public/private partnership on standards and certifications so we can be the first in the world to actually certify some of these new materials and new additive parts and things that come out of our innovation ecosystem to get the market share globally.

Senator STABENOW. That is great.

Anyone else? Dr. Williams?

Dr. WILLIAMS. Thank you, Senator.

And always great to play Michigan. [Laughter.]

I'd like to build on what Deborah just said about intellectual property. The barrier between universities and industries and understanding the different missions and creating flexible intellectual property partnerships has been around for many decades. I think universities now are becoming a lot more flexible. And indeed, we have.

We spent a year negotiating a deal with Boeing to create a master agreement that satisfied both the freedom of the faculty to do their research and publish as they wish but also to recognize the need of companies to have some protection for the investment they have put into new materials and new processes. And I think as we develop stronger and stronger industry partnerships across the nation, our ability to be flexible about intellectual property will make for a much greater flow through of the blue sky ideas that universities generate into the practical applications that industry needs.

Senator CANTWELL. Thank you, Dr. Williams.

Senator Gardner?

Senator GARDNER. Thank you, Senator Cantwell. I apologize for dropping in and out of the hearing. We have another hearing in the Foreign Relations Committee going on at the same time, so I am trying to participate in both.

Thank you very much for being here today and sharing your expertise. To the leadership of the Committee, thank you for hosting this hearing.

Now Dr. Blue, to start off a discussion with you about the National Renewable Energy Laboratory in Colorado, talking a little bit about wind turbine technology developments, my understanding is that NREL is a key partner at the Institute for Advanced Composites Manufacturing Innovation. Could you talk a little bit, specifically, about the work that NREL is doing on R&D, how the work being done there eventually leads to lower cost of wind production energy costs for business and consumers?

Dr. BLUE. Yeah. Thank you, Senator Gardner.

Yeah, NREL is leading our wind technical focus area. They're really looking at the scale up of actually innovative new technologies. One of the very first projects that they're looking and working with is the supply chain which is really key to success, we can't work on just one facet of the puzzle, is actually thermoplastic composites. And you say, well why thermoplastic composites? It really increases recyclability. And so that's one of their initial projects.

They're also looking at segmented blades. As we all know the blades are getting larger and larger and larger, and if there's a methodology such that you can actually assemble in the field, this is of great interest.

As you increase also the stiffness so they're looking at introducing carbon fiber which is a much stiffer material which limits your deflection because as you get above 55 meters you actually get deflection and you actually hit the tower.

So these are the sorts of things that they're working on, you know, increased wing capture, lower the cost through increasing wing capture, working hand in hand with industry to actually take the technology out of the lab and actually into the manufacturing floor.

Senator GARDNER. Are you able to learn from businesses like Boeing, who builds the 787 using the carbon composite technology? Can you apply those lessons learned to wind energy development, things like that?

Dr. BLUE. Yes, you definitely can.

While the funding opportunity announcement actually called out that it was not aerospace composites, we've actively embraced the aerospace industry. Boeing, sitting to the left of me, they're a premium member. Lockheed Martin is a charter member.

And if you look at the maturity of composites for the aerospace industry, we're working with essentially the entire supply chain, from the materials side to the equipment manufacturers. We're just changing the cost equation and trying to drive down costs for high volume manufacturing.

Senator GARDNER. Very good.

My next question is to your left now. I have been debating whether I call you Dr. Leo or do I try Christodoulou? Is that right?

Dr. CHRISTODOULOU. Christodoulou is fine.

Senator GARDNER. Okay, very good.

Dr. CHRISTODOULOU. But Leo is perfect also.

Senator GARDNER. Would you like to follow up on that at all? I also have some additional questions for you.

Dr. CHRISTODOULOU. Absolutely.

I actually am—we see tremendous synergies between the national labs and ourselves in the collaboration with the whole, all of the national labs.

For example, I'll be specific. We actually have Boeing folks stationed at Oak Ridge National Labs, and they've been there for a couple of years. And we're going to be increasing that presence. And the net effect of that is to bring the industrial perspective to the national labs with a tremendous simulation and modeling capabilities that they have.

You know, as we talk about the synergies that come out, across from the differences in point of view are very profound. And we can leverage the capabilities of the national labs while they leverage our knowledge of the fabrication, the scale up and the needs for day after day quality products to come off of the lines.

So it's a very productive relationship. The government, I think, and Congress and the government can really help this by the establishment of such facilities such as the manufacturing demonstration facilities, a facility that exists down at Oak Ridge. That facility brings together the academics folks from Ohio State, among other universities, the University of Knoxville, small companies, entrepreneurs and companies such as ours. And we all work together in a precompetitive, collaborative arena.

And the goal there is to accelerate the implementation of technology. You know, the government is very good at funding research and has been very effective funding research at the discovery phase. The next phase, I think, that we need to think about is the science of manufacturing, if I can call it that.

You know, there is that step, that valley of death between the innovation and the actual implementation. And the science and the technology that goes into the scale up and manufacturing is a very fruitful area for collaboration between the national labs, universities and industry.

Senator GARDNER. Well, thank you for that.

Senator Gary Peters, from Michigan, and I are working on a reauthorization of the commerce portion of the America Competes program. One of the focuses of our effort is to deal with and address STEM education and reforms and advancement we can make in STEM education.

So just briefly, I have run out of time, but briefly address this if you would.

Senator CANTWELL. No, we have to move on, I am sorry.

Senator GARDNER. Oh, okay.

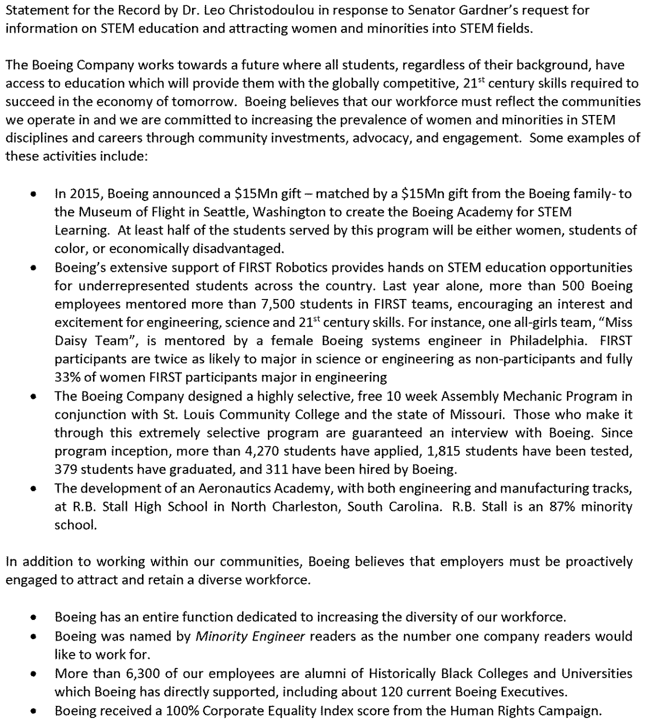
Senator CANTWELL. I mean, you can ask them for the record. That would be okay.

Senator GARDNER. Okay, just get your thoughts on STEM education and attracting more women and minorities into the STEM fields.

Dr. CHRISTODOULOU. I will be glad to provide that.

Senator GARDNER. Thank you.

[The information referred to follows:]



Statement for the Record by Dr. Leo Christodoulou in response to Senator Gardner's request for information on STEM education and attracting women and minorities into STEM fields.

The Boeing Company works towards a future where all students, regardless of their background, have access to education which will provide them with the globally competitive, 21st century skills required to succeed in the economy of tomorrow. Boeing believes that our workforce must reflect the communities we operate in and we are committed to increasing the prevalence of women and minorities in STEM disciplines and careers through community investments, advocacy, and engagement. Some examples of these activities include:

- In 2015, Boeing announced a $15Mn gift – matched by a $15Mn gift from the Boeing family- to the Museum of Flight in Seattle, Washington to create the Boeing Academy for STEM Learning. At least half of the students served by this program will be either women, students of color, or economically disadvantaged.
- Boeing's extensive support of FIRST Robotics provides hands on STEM education opportunities for underrepresented students across the country. Last year alone, more than 500 Boeing employees mentored more than 7,500 students in FIRST teams, encouraging an interest and excitement for engineering, science and 21st century skills. For instance, one all-girls team, "Miss Daisy Team", is mentored by a female Boeing systems engineer in Philadelphia. FIRST participants are twice as likely to major in science or engineering as non-participants and fully 33% of women FIRST participants major in engineering
- The Boeing Company designed a highly selective, free 10 week Assembly Mechanic Program in conjunction with St. Louis Community College and the state of Missouri. Those who make it through this extremely selective program are guaranteed an interview with Boeing. Since program inception, more than 4,270 students have applied, 1,815 students have been tested, 379 students have graduated, and 311 have been hired by Boeing.
- The development of an Aeronautics Academy, with both engineering and manufacturing tracks, at R.B. Stall High School in North Charleston, South Carolina. R.B. Stall is an 87% minority school.

In addition to working within our communities, Boeing believes that employers must be proactively engaged to attract and retain a diverse workforce.

- Boeing has an entire function dedicated to increasing the diversity of our workforce.
- Boeing was named by *Minority Engineer* readers as the number one company readers would like to work for.
- More than 6,300 of our employees are alumni of Historically Black Colleges and Universities which Boeing has directly supported, including about 120 current Boeing Executives.
- Boeing received a 100% Corporate Equality Index score from the Human Rights Campaign.

Senator CANTWELL. Thank you, Senator Gardner. Sorry, we are just trying to fit everybody in.

Senator Warren?

Senator WARREN. Thank you, Madam Chair.

We have heard a lot today about the changing nature of manufacturing, innovative technologies that have enabled manufacturing operations to become smarter, more efficient, more complex. And just a couple of weeks ago the Department of Defense announced funding for a new $317 million innovation institute in Massachusetts that would focus on researching revolutionary fibers and textile manufacturing. I want to add, it is about how to bring those to markets. So it is both halves. It is the science and the marketing and the development of it. So we really have something that works here.

You know, investments like this are not going to make a big difference, I understand, in manufacturing as we go into the 21st century. But how we make things is not the only thing that is changing. The rise in advanced manufacturing also places new demands on the people who actually do the work.

So let me start there. Ms. Wince-Smith, your testimony highlights some recent developments in manufacturing. As manufacturing becomes more reliant on advanced technologies, what trends are we seeing in what employers demand from their workers in terms of education?

Ms. WINCE-SMITH. Thank you, Senator Warren.

Well I think we discussed a little bit about this in some of our testimony but it's really workers who are not performing routine jobs that do not require quantitative skills and judgment.

Increasingly the workforce in any manufacturing environment one has to exercise judgment. They have to be prepared to insert themselves in a position when in the past they stood on an assembly line, and the quantitative skills that have not traditionally been taught for this type of work is a tremendous barrier for us now.

One thing I think that's a very exciting model to look at for how some of these skills are being developed is really the training programs that we're seeing with the pipefitters and plumbers.

Senator WARREN. Fair enough.

But I just want to push on this a little bit more because I actually found some data on this. American manufacturing jobs help build America's middle class, but today those jobs require a lot more education.

Just since 2000 the share of manufacturing workers with college or advanced degrees has gone up by seven percentage points. And that is just in 15 years basically, that has happened.

But at the same time that the importance of post-secondary education has grown, the cost of receiving the education has skyrocketed. College students today will pay, adjusted for inflation, about 300 percent of what someone would have paid a generation ago.

Today 70 percent of four-year college grads must borrow money to make it through school, and the U.S. Government is profiting off the backs of these students with the student loan program. I think that is obscene.

So let me ask, Ms. Wince-Smith, what do rising levels of student debt mean for the growth of the manufacturing sector?

Ms. WINCE-SMITH. Well it's a very serious issue, as you described, because it acts as a barrier for students coming in and getting the advanced education they need. And it also limits their opportunities as they move into the workforce as well because they are saddled with this debt. I think this raises a whole much, a broader discussion around some of the structural issues in our higher education system.

But also, when you look at the continuum, the role of the community colleges is so important in the infrastructure we're talking about and the partnerships that they have both with companies and then, you know, sort of these manufacturing ecosystems.

So I do think that the student debt issue is one that relates to this, but even more important is how are we going to ensure that the next generation of American young people have the STEM skills, have the interest of even going into a manufacturing environment?

I mean, one of our Council on Competitive members, who spoke recently testified, the CEO of Snap On which is a fabulous manufacturing company. He said, how many in the room would feel happy if their son or daughter said they were going to go in and work in a manufacturing environment? That's considered the consolation prize now for America as opposed to being a prize that's going to deliver a good standard of living.

Senator WARREN. Well you know, I think as we talk about the question about how we build a manufacturing base, certainly part of that is to make the investments in R&D, to make sure that our trade policies benefit, not just big business and their investors, but that they work for all Americans.

But it also means investing in our most valuable asset, and that is American workers. We face a choice. Are we going to invest in post-secondary education and training so that our workers can get the skills they need to develop good careers and they have financially secure lives, or are we going to keep saddling them with mountains of debt to pay for that education?

The only way that American manufacturing will truly rebound in this country is if we start taking seriously our investments in people, and that means helping people get an education without getting crushed by student loan debt.

Senator WARREN. Thank you.

Senator CANTWELL. Thank you.

Senator Cassidy?

Senator CASSIDY. I have a question for anyone.

We have discussed various types of alternative materials. What about concrete? For example, it is very energy intensive, and we use a heck a lot of it. I think I just saw that the United States is the third leading production, and it is a tremendous source of greenhouse gases. So do we have alternative for concrete? That is one example. Rubber is another. Anybody?

Dr. WILLIAMS. I can't speak to concrete, but certainly rubber has been researched in many different universities, different sources of rubber, actually dandelions grown in Northern Ohio are being used as a—to develop alternative sources of latex. So there are different bio approaches to rubber.

I have not heard of any significant alternatives to concrete just given the scale of the use of concrete across the nation.

Senator CASSIDY. Okay.

Ms. Smith, you lead off your testimony speaking about the lower energy costs in the United States relative to other countries, and you seem to tie that to this research into alternative materials. Is it fair to say that oftentimes the energy input into something of advanced manufacturing might be higher than in non-advanced manufacturing? Is that true or?

Ms. WINCE-SMITH. Absolutely.

And you know, having this situation in the United States where we've moved from being an energy weak country to an energy strong country has really been transformational. Our costs of energy now are four times less than Germany. Just a huge competitive advantage. And it—

Senator CASSIDY. So it is a huge competitive advantage, but I am gathering also you are implying essential to having a, what is, a cost effective, a favorable cost benefit ratio of these advanced materials relative to other countries. Is that?

Ms. WINCE-SMITH. Yes, because of the cost of the feed stocks that were so, you know, part of the energy costs.

Senator CASSIDY. So if you have composite carbon that goes into a plane that achieves 30 percent less fuel usage, 30 percent greater fuel efficiency, that carbon coming from natural gas is a feed stock.

So it strikes me as a little ironic. Those who think they are saving the Earth by wanting to not develop our natural gas resource. I am hearing from you that that would actually be counterproductive. Not only will we lose our feed stock but it would be more cost prohibitive if we do not have our cheap feed stock in order to create this carbon fiber which then saves us all this fuel.

Ms. WINCE-SMITH. Well, I will say that the U.S. Council on Competitiveness, for many years and increasingly in recent years, has really argued for having a balanced energy portfolio including utilizing our tremendous bonanza of natural gas and the impact it has on, not just our chemical industry, but on the other dimensions you've described.

Senator CASSIDY. Okay.

Now let me ask as well and this is more trade policy, but you are all thoughtful people. If we come up with this great intellectual property, and I always take as my prism that working family, that gal or that guy that does not have an associate degree. We spoke about how so much education was required, but the reality is there is a group of folks who are going to make their living pulling a wrench. And they are not going to go to college, for whatever reason.

I have been monitoring what people have asked and it seemed like the continued mantra is that we have to invest in worker training. I totally get that. But there is still going to be a population of workers who, for whatever reason, do not achieve that higher level of training.

It seems as if inherent in everything we have been saying, we may develop the intellectual property but depending upon trade regulations that intellectual property may be utilized in China after we have developed it, or India or Mexico, as opposed to bringing jobs here. There is nothing inherent in anything we are speaking of that the job created downstream would be created in the United States unless it is in a Jones Act shipyard in Alaska. Except for that Jones Act shipyard is there any other, and I guess maybe if we have more energy efficient energy production, that is domestic by definition. Is there anything besides those two examples in which the benefit would necessarily accrue to workers having such a hard time now?

I am taking that as a no. [Laughter.]

Ms. WINCE-SMITH. Well I think one of the ways that we'll accrue is how all of this innovation and the transformation of manufacturing and energy is absolutely essential for our economic growth. I mean, one of the challenges our nation is facing is very flat productivity and of course, that's directly tied to wages and employment and also our economic growth.

The Gallup Corporation estimates we have to really reach 3.75 percent in economic growth in order to keep pace where we are right now.

Senator CASSIDY. I totally accept that, but greater efficiencies does not mean a greater number of jobs. Greater number of jobs is obviously new markets, new technologies for previously unmet needs. But I totally accept what you are saying. I yield back. Thank you.

The CHAIRMAN. Thank you, Senator.

Senator King?

Senator KING. Thank you.

One of the advantages of being last in line is you get to listen, and this has been an excellent presentation. I think the best line I have ever heard about manufacturing is that you cannot build an economy on taking in each other's laundry. Somebody, somewhere has to make something.

Dr. Blue, I want to give you a name and a phone number. Habib Dagher, D, A, G, H, E, R. He is the Director of the University of Maine, Advanced Composite Center. He is one of the most dynamic individuals I know, and I want you guys to become acquainted because they are doing amazing things.

They have, for example, a huge testing facility for wind blades. They also have, essentially, a model of the ocean. They have a tank that can model any situation, any storm, any wave situation on a scale for testing offshore facilities, particularly offshore wind projects.

They have also been doing composites research for 20 years. One of the most important areas, and I want to urge you to please look at this, is nano cellulose polymer technology. We have a gold mine of fiber in Maine which historically has been used to make paper. The paper industry has been brutally hammered in the last five or six years. We have lost something like five paper mills to the combination of lower dollars and lack of demand, principally.

We need a George Washington Carver of fiber. I remember from the sixth grade, George Washington Carver was the scientist who figured out a hundred ways to use peanuts. We need that kind of research. University of Maine is doing it. You could be a huge help.

So I hope you will get in touch with Habib. You will enjoy getting to know him, and I think there are some real partnerships to be had.

So if you can find a question there you are welcome to it, but—[Laughter.] That was more of a statement.

Dr. BLUE. No Senator King, thank you very much. I will follow up on your recommendation. I am aware of the work, and we have talked to them previously. We have our leader of our materials and processing reaching out to them to see if they can become part of this institute. So—

Senator KING. Thank you.

Dr. BLUE. Yup, thank you.

Senator KING. Ms. Wince-Smith, we were talking about advanced manufacturing but the implicit question is what is the Federal role? That is why we are here. It seems to me, hearing you today, it is R&D and training workforce. Would you concur?

Ms. WINCE-SMITH. I would, Senator.

But I would also add that the Federal Government has a very important, increasingly important, role in helping develop the shared infrastructure for 21st century manufacturing. And that encompasses the carbon facility, for instance, we've been talking about at Oak Ridge. It encompasses having a network of the most advanced supercomputers really in the world, and our companies and our researchers being able to access that.

Senator KING. What if the Federal Government stopped funding all of this altogether? Just stopped and only built ships and airplanes and defense and Navy and maybe some agriculture programs?

Ms. WINCE-SMITH. I think it would be very deleterious to the long-term future of our country because so much of the innovations that we're talking about have depended on these, the long-term stable investments in research and development and also having, for instance, in the national laboratories.

I mean, if any country had to try to replicate the system we have today it would be virtually impossible. These are absolute treasures for us because they work at the frontiers but they also work in a multidisciplinary way and they make things. You know? These national labs have a history and tradition of also fabricating. And so getting our companies to team and vice versa is a huge strategic advantage we have. So nurturing those for complex government missions, including collaboration and our national security front. We haven't really talked about that too much, but at the end of the day we have to be a great manufacturer or we're going to have tremendous vulnerabilities in national security.

Senator KING. In fact, you can argue when you go back to World War II it was our manufacturing strength coupled with our armed forces that actually won the day. I remember reading about people in Japan looking up and just seeing all these airplanes coming. How in the world did they do that? That is part of our national security for sure.

I am going to have your answer that you just gave reprinted and put in the congressional record because often times around here people talk about the Federal Government does not do anything or cannot do anything right. I think research and development is one of the crucial functions. Of course, so is job training because we are having these transitions.

I want to commend to you a problem though, and that is what I call the stranded worker problem. You can have a worker who loses their job in a traditional manufacturing industry and then you create a new job that day in computer programming to program the robots. That person who lost the job cannot necessarily do the new job. On paper, it is no net job loss. In reality it is a tragedy for a family.

We have to be focusing on workers in their 40's and 50's who are being displaced by technology and robotics, and how do they get back into the workforce?

I am out of time but I hope you will all supply some thoughts for the record on that because I think that is one of the problems facing our country. Training of young people, but also supporting, retraining and working with those who are being stranded by the changes in the economy.

Madam Chair, I am out of time. Thank you very much.

The CHAIRMAN. We are out of time, but I am interested in the response. So I will use it on my time because I think it is very pertinent, very relevant to where we are to ensure that where we are doing right, by not only our young people, but those who are transitioning to other opportunities as well.

How do we stay ahead?

One of the things that we are looking at in Alaska, we want to make sure that when we are able to move our natural gas to market, we need to know that we have got the trained Alaskan workforce. But you cannot train them up too soon because then you do not have the jobs. So you have trained them for something that does not exist yet.

Knowing how quickly things come, how do you make sure that that pipeline is significant enough? But again, I think to your point, for opportunities that we might not even know yet. So I will throw Senator King's question out to all the rest of you.

Dr. Christodoulou?

Dr. CHRISTODOULOU. Madam Chairman, I feel passionate about the retraining aspect of our educational program, because I remember when I was a student at the university. George the machinist, I could give him a little hand drawing and he would create an excellent piece of engineered machinery. And that person can now, that kind of skill, can be translated to the new economy. That person that used to do machining can now do other manufacturing.

I know it's hard to do. It's hard to retrain people, but it's possible through the schools, the community colleges and hands on training programs that we have.

For example, companies like ours, like The Boeing Company, every year we take on the order of 1,500 interns that come and spend time with us. Now these interns are typically young, but they don't have to be.

So, you know, we look forward and we want to see more retraining because the technology change of the rate of change of technology is such that it's unlikely that somebody who has been trained in one field, you know, a long time ago, will remain relevant in the new economy.

Additional to that, the new generation, I think, are very—of our people are more adaptable to, what I call, the digital revolution. They like to change.

The days of where somebody had a 40-year career in a single field are fast diminishing. People like to change jobs and go from one interest to the other.

And I think that culture change can be aided by the Federal Government and Congress in facilitating this retraining, the local retraining programs.

The CHAIRMAN. Well Doctor, let me interrupt for just a moment because I do not disagree with anything that you say, but sometimes I feel that our institutions are not as nimble as our people. I go back to your example, Mr. Ward, about the app and just being able to move quickly. There are probably some that would look at that and say, too fast, does not fit with the construct here. I am reminded of some of the challenges that our military are facing. They have incredible skills they have acquired throughout the military, but those skills then do not translate to the certificate that is needed once they are out.

So making sure that there is a greater flexibility, I guess, is the word, or maybe just more nimble because I worry that our institutions are locked into where they are today rather than projecting forward to the next opportunities.

I want to ask one more question here, and I will just throw it out to all of you. You can either continue on this question or help answer me this one. How do we move the amazing R&D that we see out there, what we have coming from our national labs, from our research universities? How do we transition this technology out of the lab and into the marketplace? Because in this Committee we hear time after time after time that you have these great research places but we talk about the valley of death, how they move or fail to move from one and actually translate into the marketplace. How do we do a better job of that transition?

Ms. Wince-Smith?

Ms. WINCE-SMITH. I'll jump on that one, Senator Murkowski.

The CHAIRMAN. Okay.

Ms. WINCE-SMITH. One of the things that is going on in this whole space of, you know, from discovery to deployment are new models that are being created of partnerships. I'll just give some examples from the national labs. Not too long ago there was this perception that there was all this valuable technology sitting on a shelf in these national labs, and we just needed to have an efficient process for licensing and it would go out and be deployed in industry.

And certainly in universities and labs there are some technologies that really are ready to be licensed. We know of some pharmaceutical blockbusters and things that have come out of that. But for the most part in order to do the maturation and build the part, there has to be a partnership.

And so, speaking of the national labs, we're seeing now some very deep strategic partnerships with individual U.S. companies teaming with these labs but also in the model of some consortia as well.

That's one model I think where we have some progress and a competitive advantage compared to other countries, really, of working that way.

I'll give you another example. General Electric, they have a major partnership with Livermore in additive manufacturing. And they're already a big player in that. But their teaming now in some very advanced technology to accelerate that. That's a great example that we'll get that into marketplace, and other companies have the right to come in and do that sort of thing as well. And we heard about Boeing's deep partnerships.

The other issue though is some of these innovative early technologies where new companies form and how you get the venture capital and scale. I think that's the biggest problem we have because we saw at the height of the early investment in clean energy, that so many of those technologies and companies they reached a certain point and they went offshore.

We have cases where the Chinese came in and bought companies that we had nurtured to a certain point, and we couldn't scale them and they were gone. That, to me, is an area where we all should be working very hard to figure that one out.

The CHAIRMAN. So let me ask, Dr. Blue and Dr. Williams, from the national labs' and from the university's perspective, how do we get it from you out into the marketplace?

Dr. BLUE. Thank you, Senator.

So the real key to success is people, and the best tech transfer is people. So having people work side by side integrates the supply chain.

The vast majority of the projects that we're executing are industry-driven projects. You have to have the pull from the industry and then you have to bring the supply chain along such that when you have success all the facets that are needed to really cross the threshold into commercialization, it's there. And that's where we've had our most success by far.

So you know, we've worked in everything from turbo chargers and diesel engines, again, where you had the big OEMs doing the pull, the supply chain. Three million turbo chargers today in Cumming's engines. Those sorts of things.

Additive manufacturing. We're fortunate that the MBF is the home of the Shelby Cobra. The story behind that is the fact that you had the equipment manufacturers in there. You had the materials providers. You had local SMEs that did the surface finishing. So it was a large, integrated team that really made that happen with each person bringing their own innovation where really innovation is at the crossroads when you get people with different backgrounds working together.

The CHAIRMAN. Dr. Williams?

Dr. WILLIAMS. Chairman Murkowski, thank you.

I think one of the keys is to have a much more flexible set of opportunities for our young professors, in particular, who see the opportunity to take their ideas and turn them into commercial products as something that they would like to do. This was not traditionally a role of professors when I started. And indeed, we, at the universities have changed the tenure and promotion requirements to encourage professors to create new intellectual property, to patent their ideas and to have both the time and the opportunity to take those ideas and start companies themselves.

Last year at Ohio State there were 52 new companies started out of the university. That is not as good as it should be in comparison with some of our fine competitors, but nevertheless, there is increasing amounts of that kind of thing going on. The generation of young professors that we're hiring see the world very differently, again, to previous generations and expect to be able to start their own companies.

Students do the same, and the opportunity for innovation at all levels in today's universities are much greater than it used to be.I'd also like to address the comment you made about our inflexibility. And there are certainly good reasons for that and within our standard degree programs we are somewhat corralled by the accreditation requirements to deliver certain amounts of knowledge in a certain period of time.

But beyond that at Ohio State and many of the universities at the graduate level, the creation of certificate programs that may buildup to formal degree programs or may just stay as very focused certificate programs to bring a skill set to an individual either who is a graduate student or who is coming back for retraining. This can be done online in many universities including Ohio State which has literally dozens or even hundreds of online programs that don't necessarily lead to degrees but bring a skill set that an older person might value when they want to move into a different part of the workforce. So there is flexibility there but it's not always in our catalogs when you read them online.

The CHAIRMAN. Understood.

Senator King, did you want to weigh in?

Senator KING. Yes.

The CHAIRMAN. Dr. Christodoulou or Mr. Ward, I know that certainly in Ketchikan what we have seen through the University of Alaska Southeast and their job training programs that are very specific to the shipyard there and have been extraordinarily helpful for the local people. I think there is that nimbleness if you can get the funding through your university programs. So I do not mean to be critical of all of our institutions in general here.

Dr. CHRISTODOULOU. Madam Chairman, I just wanted to give an example of a Boeing program in Utah and the local industry there where we are engaging with high schools to bring young people into the factory, and not just into Boeing but to the broader community. We're doing this with Governor Herbert.

The program has just kicked off and they have internships within the industrial corridor in the Salt Lake region, and that enables them to get first-hand experience of these types of jobs and the new jobs that they need.

So the companies that we're experimenting with are a number of different models to enable that transition and that ability to experience the work environment at an early stage.

The CHAIRMAN. Great.

Mr. Ward?

Mr. WARD. Well Senator, again, thank you very much.

I guess the—your question about what are we doing for the 40- and 50-year olds that are transitioning out of jobs to new jobs is one that we're going to be faced with in Alaska, particularly with the price of oil the way it is and our economic circumstances related to our state deficit.

Our education system is going to take big cuts, our workforce investment system is going to take big cuts, and we're going to have a lot of people out of work or there's a very good likelihood of that.

So how do we rapidly respond to a situation like that in a really small economy with not a huge demand for workers? And I think part of the answer, it has to do with nimbleness and I've heard a lot of discussion about relationships and collaborations here. And it's to begin looking at the workplace as not just a place to work, but as a place to become a whole human being really.

We're beginning to talk about our shipyard as a college for a human being where you can come and not only learn how to work, but you can come and learn more about the world and more about to help become part of our community.

So how does that translate to a transitioning worker that is 40- or 50-years old? We are beginning to have internships where we're having young people come in to the yard. We've got a young lady, Marsha Tobiack from Bristol Bay, that's just an awesome young worker. We take that model now, I believe, working with our universities and campuses, and begin to look at the workplace as a place to learn how to retool workers.

So my point being develop in workplace training methodologies that already exist. And rather than having adult workers go to colleges and career centers for retraining, begin putting those on-the-job training opportunities where transitioning workers are receiving college degrees and assistance from the Department of Labor right on the work floor.

And when you talk about nimbleness I think that's the type of things we need to be thinking about across the board to take care of some of our employment issues that are coming up in the state.

The CHAIRMAN. I appreciate it. Thank you.

Senator King?

Senator KING. On this point of training, a program we used when I was in state government in Maine. We tend to think of training over here in training institutions and employers over here.

One of the programs we used was a program where we would fund the training that the employer would conduct because then they were training people for the jobs that they really had. There was not any danger of a mismatch. I think that is something we ought to think about instead, and I am not saying eliminate the other system, but this would be a direct funding. If Boeing says we need 10,000 people to staff up a new facility in Maine, for example, just to take it there. [Laughter.]

But to provide direct funds to you to provide the training rather than have that link necessary then you can do the training that you need. Of course, there needs to be accountability and those kinds of things.

But I think, Madam Chair, that is something we ought to be thinking about as we are thinking about this issue of training, because that's one of the essential functions moving forward to remain competitive and to build on the technological advances that we're having.

That is just one idea that we used with quite a good deal of success in Maine during the 90's.

Thank you.

The CHAIRMAN. Thank you.

This has been very informative. I truly appreciate all that you have provided.

I am going to apologize on behalf of many of our colleagues. We have so many different committee meetings that are all scheduled at the same time, so we are all jumping up and down like jack-in-the-boxes here a little bit this morning.

Do not take that as a lack of interest. I think the fact that we had such a good number of Committee members that were in attendance today indicates, clearly, an understanding and an appreciation that as we work for a stronger economy and greater jobs and good paying jobs for our families around the country that staying, kind of, ahead of the curve is going to be important in ensuring that we have the skills that are needed in order to be competitive in a very global society, that we continue to lead. And you are helping us with that, so thank you very much.

With that, the Committee stands adjourned.

[Whereupon, at 11:55 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
Hearing: The Status of Innovative Technologies in Advanced Manufacturing
April 12, 2016
Questions for the Record Submitted to Dr. Craig Blue

Questions from Chairman Lisa Murkowski

Question 1: As the Institute for Advanced Composites Manufacturing Innovation moves into the shared space with your fellow National Network for Manufacturing Innovation institute, the Lightweight Innovations for Tomorrow, how will the institutes leverage the resources, expertise, and best practices learned from one another?

Answer 1: Thank you for the inquiry. The organizations are already sharing industry best practices through frequent, purposeful communications and development of impactful workforce training programs that benefit the entire automotive ecosystem.
The strength of the collaboration is the co-location. Current automotive prototypes are being produced with multiple materials such as magnesium, aluminum, steel and composites. Future manufacturing processes require multi-material systems, equipment and expertise – all of which are available through the partnership.

Question 2: The National Network for Manufacturing Innovation (NNMI) plays an integral role in advanced manufacturing, and in many ways it serves as the functional tie between DOE and everyone else involved with research, development and demonstration within the advanced manufacturing industries. Please explain how the NNMI works from your perspective, and how it is useful when it comes to innovating advanced manufacturing technologies and processes.

Answer 2: The public private partnerships created by the NNMI combine the best of federal and industry resources to enable rapid deployment of technology integration. Government can catalyze and bring the Universities, National Laboratories and Industry together to address challenges.

Once manufacturing challenges are identified by industry, the institute brings together the necessary intellectual and capital capability. In order to provide the most impact, we are streamlining agreements to allow rapid access to capabilities. Speed is critical in advanced manufacturing innovation.

The institutes are creating innovation at the crossroads by bringing people with different backgrounds together to solve problems. By coupling basic to applied science, we are expanding potential applications for advanced manufacturing technologies and materials.

Questions from Senator Joe Manchin III

Question 1: As you may know, West Virginia is home to the Robert C. Byrd Institute for Advanced Flexible Manufacturing (RCBI) which has centers in Bridgeport, Charleston & Huntington. RCBI serves all of West Virginia and portions of Pennsylvania, Maryland, Virginia, Kentucky and Ohio primarily from four West Virginia-based Advanced Manufacturing Technology Centers.

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Given RCBI's capabilities, its state-of-the-art service offerings have been completed in 17 states across the United States. The RCBI's Bridgeport Center operates a Center of Excellence for composites in support of NASA. Working directly with NASA engineers as well as local composites manufacturers, RCBI assists in the development of composites materials used for space flight vehicles. The partnership with NASA helps to infuse the West Virginia-area manufacturing sector with new opportunities for economic development.

RCBI also offers Additive Manufacturing (AM) technology with 3D Printers through its Design Works labs and is a national Center of Excellence for composite materials providing support to as first-tier Department of Defense suppliers in West Virginia. RCBI has worked with the Oak Ridge National Lab through a business partnership with Northrop Grumman. And the Institute has worked with Boeing on R&D efforts focused on out-of-autoclave processes.

I highlight these efforts because I would encourage you, Dr. Blue, and the other witnesses to work with RCBI to identify opportunities for the siting of more advanced manufacturing facilities in West Virginia.

West Virginia continues to experience unemployment rates higher than the national average and, with the growing need for advanced manufacturing jobs, I believe there is significant opportunity in my home state that can be leveraged, particularly around small manufacturing enterprises (SMEs).

My staff has spoken with RCBI and they are happy to act as a central wheelhouse to help your organizations explore potential areas for future partnerships with the SMEs. Please comment on your work with SMEs as well as discuss opportunities to work with West Virginia organizations such as RCBI.

Answer 1: Thank you for your questions and the capability highlights. As a national institute, we're solving manufacturing challenges that span throughout the country.

Through IACMI's partnership agreement with the American Composites Manufacturers Association (ACMA), our national footprint has grown from 32 member states and over 130 members to a membership base that includes 50 states and over 500 members. In addition to membership representation, we continue to expand our facility capabilities through a co-location in Michigan, a facility partnership in New York and a soon-to-be-announced partnership on the West Coast.

As you note, SMEs represent an important group in the manufacturing supply chain. IACMI-The Composites Institute welcomes members with varying backgrounds and in fact, SMEs comprise approximately 60% of our membership base. Your suggestion of working with SMEs is directly in line with our vision as a national institute.

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We welcome discussions with RCBI on future collaborative opportunities.

Question 2: It goes without saying that the natural gas renaissance in this country has led to the siting and re-siting of chemical facilities here at home. In fact, last week, the American Chemistry Council reported that "the U.S. chemical industry investment linked to … natural gas and natural gas liquids from shale formations has reached $164 billion. Forty percent of the investment for the 264 projects – new facilities, expansions and factory re-starts – is completed or underway..."

As you know, West Virginia is a net energy exporter. According to the Energy Information Administration, West Virginia has 8% of the country's natural gas reserves and 8.7% of the country's recoverable coal reserves at producing mines.

Further, because of energy production in the Marcellus Shale, natural gas liquids used as feedstocks for plastics manufacturing are more accessible and affordable.

Dr. Blue, to what extent do your organizations consider accessibility, reliability and affordability of energy resources when deciding where to site your advanced manufacturing facilities?

Answer 2: As you note, energy is a key factor to be considered as organizations select manufacturing sites. We support industry decision makers as they make informed decisions on manufacturing facilities that best meet their needs.

Question from Senator Mazie K. Hirono

Question: I understand the Institute for Advanced Composites Manufacturing Innovation began work just nine months ago, but what approach is the Institute taking to speed commercialization of the research and development efforts that will be supported by the Institute, including involving small businesses?

Answer: Thank you for your advocacy of small businesses. The institutes are creating innovation at the crossroads by bringing people with different backgrounds together to solve problems.
The public private partnerships created by the NNMI combine the best of federal, academic, and industry resources, which include small businesses to enable rapid deployment of technology.

Once advanced composite manufacturing challenges are identified by industry, the institute brings together the necessary intellectual and capital capability to address the challenge.

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Questions from Chairman Lisa Murkowski

Question 1: Please describe, since moving from the Department of Energy to Boeing, how the vision for the future advanced manufacturing is aligned and/or differs between government and industry?

Answer: It is really a partnership between the federal government, industry and academia. As you know, the federal government has a long history of supporting scientific research in the "discovery phase" and those investments have led to many innovations. In a similar manner, investment in manufacturing-oriented basic research can lead to effective and rapid implementation of those innovations within the United States and result in high quality jobs and fulfilling careers. This committee and Congress can also help by investing in education, training of our young people and re-training of our existing workforce in new manufacturing technologies. Such action can bring to our people the expertise and tools needed to compete in the new economy that is based on the digital/information technology revolution. Equally important is the need to ensure the U.S. provides a legal and regulatory environment where businesses not only want to create but also commercialize their innovative products and services.

Question 2: In your written testimony, you mentioned briefly in your discussion of Boeing's commitment to energy efficiency the term "out-of-the-autoclave composites." Could you elaborate on what that means?

Answer: Current Carbon Fiber Reinforced Plastics (CFRP) technology employs a class of materials, called Thermosets, which require a cross-linking chemical reaction ("curing") under pressure to achieve their properties. This is normally accomplished by placing the uncured preform in an autoclave. The autoclaves can be massive, over thirty feet in diameter, and have a large mass and equipment within them. It is therefore necessary to expend energy to heat up the entire equipment mass, whereas the mass of the component that is being cured is a tiny fraction of that of the autoclave.

Out-of-the-autoclave composites, on the other hand, do not need an autoclave and thus save a substantial amount of energy during manufacturing, while at the same time providing the same energy and fuel efficiency in service. Furthermore, a different class of CFRPs that are based on thermoplastic polymers do not require curing at all further—reducing energy consumption. Boeing has pioneered the development and use of out-of-the-autoclave composites, flying the first flight-critical out-of-the-autoclave component on our Phantom Eye experimental airplane, and is increasing the amount of thermoplastics on our platforms significantly.

Question 3: In your written testimony you mention that Boeing's 787 Dreamliner uses composite materials extensively, and that ceramic matrix composite technology will continue to advance engine designs in the future. Please elaborate on the ways that a passenger, perhaps without knowing it, will experience and benefit from advanced manufacturing technology innovation when he or she steps onto a cross-country flight, for instance, 10 years from now.

Answer: Boeing has been investing heavily to move product lines forward in their efficiency due to customer demand. Use of these materials ensures that new aircraft will exceed the highest fuel efficiency of today's airplanes, and each new generation of aircraft will be roughly 15-20% more efficient than the model it replaces. Greater efficiency also means that aircraft can travel longer distances with less fuel so planes will have greater range and increased cargo capacity.

The increased performance and durability of the composite materials allows our 787 Dreamliner aircraft to operate at higher pressures within the passenger cabin. This permits higher oxygen and humidity levels which translates into a more comfortable environment and reduced "jet lag" for the passengers. We hear a large number of very positive testimonials from passengers following flights on our 787s.

Question 4: What are the unique types of expertise in advanced manufacturing found in our great research universities and in our national labs? We would like our efforts to be greater than the sum of its parts. Therefore, how do we leverage these valuable resources in a strategic way to eliminate duplication of efforts and maximize return on investment?

Answer: In many cases new technologies are far too costly and interdependent to be developed solely by the private sector. The establishment of a manufacturing infrastructure that includes "hands on" training is important to our combined mutual efforts. For example, the Oak Ridge National Laboratory's Manufacturing Technology Demonstration Facility, provides a manufacturing-relevant environment for academia, National Labs, entrepreneurs, and small and large companies, to explore, evaluate, and collaborate on new manufacturing technologies in a pre-competitive way. The synergies that emerge from these collaborations can provide for a globally competitive U.S.-based manufacturing infrastructure.

Question from Ranking Member Maria Cantwell

Question: Dr. Christodoulou, Pacific Northwest National Lab has long collaborated with Boeing on advanced manufacturing of lightweight materials and composite aerospace structures to improve their cost and performance competitiveness.

Most recently, PNNL worked with Boeing on development of the 787 Dreamliner on titanium alloys, as well as composite manufacturing. This research has helped lead to significant fuel and energy savings.

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So, my question is, how do we further incentivize these public private partnerships?

Answer: It is really a partnership between the federal government, industry and academia. As you know, the federal government has a long history of supporting scientific research in the "discovery phase" and those investments have led to many innovations. In a similar manner, investment in manufacturing-oriented basic research can lead to effective and rapid implementation of those innovations within the United States and result in high quality jobs and fulfilling careers. This committee and Congress can also help by investing in education, training of our young people and re-training of our existing workforce in new manufacturing technologies. Such action can bring to our people the expertise and tools needed to compete in the new economy that is based on the digital/information technology revolution. Equally important is the need to ensure the U.S. provides a legal and regulatory environment where businesses not only want to create but also commercialize their innovative products and services.

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Dr. Christodoulou, to what extent do your organizations consider accessibility, reliability and affordability of energy resources when deciding where to site your advanced manufacturing facilities?

Answer: Boeing has a clear strategy and commitment to take action to reduce energy intensity in our operations. When contemplating future Manufacturing or Administrative site locations, the Boeing Company takes numerous factors into consideration, including, but not limited to, factors around energy resource options. We understand that designing products and facilities with energy efficiency as a basis is crucial to our long-term performance objectives. For example, 100% of our electricity in our 737 plant in Washington and 787 plant in South Carolina comes from renewable energy, and we grade ourselves on performance indicators related to water usage, emissions, and waste to landfill.

Question from Senator Shelley Moore Capito

Question: One of the ways we've been able to produce a modern technical workforce in West Virginia, is through the partnerships that our local Community Technical Colleges have forged with Toyota and Procter and Gamble, who operate manufacturing plants in my state.

- In your opinion, what are some ways to better encourage private companies to engage with local community and technical colleges, so that our workforce is better equipped to understand the new technological skill set required for advanced manufacturing?

Answer: Boeing operates a number of highly successful workforce training partnerships in conjunction with regional educational institutions across the country. In an employer driven training partnership, a company like Boeing will work with partner schools to communicate skills needs, assist in curriculum design and program implementation, and ultimately hire from the pipeline that is trained by the partner school. This highly effective model ensures students have the skills employers require for in-demand jobs. Further, these employer driven training partnerships provide high quality career and technical education not only for future Boeing employees but also for individuals hired by our supplier partners—many of whom are small and medium-sized businesses.

One of these highly successful employer driven training programs is the Washington Aerospace Training Resource Center ("WATR Center"). The WATR Center is operated by the Edmonds Community College and the Renton Technical College. The Boeing Company worked closely with both schools to develop curriculum supporting six aerospace industry certifications and provided more than $2.5 million worth of materials and equipment to create a simulated work environment. Since 2010, the WATR Center has provided certificate level training to more than 3,050 students. Of these students, more than 1,950 applied for a job, and more than 1,680 were then hired. Approximately 58% of these students were hired by Boeing and 29% were hired by other aerospace companies, such as our supplier partners.

Boeing has also developed partnerships with school districts to begin providing relevant advanced manufacturing skills education at the high school level, and in some cases enrolling these students in work-based learning programs, such as internships, before ultimately hiring them upon graduation. These partnerships exist in states such as Oregon, Utah, South Carolina, and Washington— where more than 150 local high school and skill center students were hired last year. In these ways, and others, The Boeing Company is working to ensure a robust pipeline of students with globally competitive 21st century skills.

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Questions from Chairman Lisa Murkowski

Questions: The Ketchikan shipyard has evolved greatly over the past two decades.

a. How do you expect advanced manufacturing materials and techniques to change the way you build ships in the future?

Answer: Vigor Alaska is adopting mobile technology that is disrupting how shipyards communicate between front line workers and other project managers engaged in scheduling, reporting, and project performance.

Several years ago, Vigor discouraged the use of cell phones by production workers on the deck plates. In late 2014, Vigor was awarded a negotiated contract with the State of Alaska (SoA) to construct two ferries for the Alaska Marine Highway System (AMHS) at below market prices. As a result, Vigor must develop new strategies to reduce the cost of building ships in Ketchikan.

A significant cost driver in shipbuilding occurs when variances are found by production workers on the shop floor who are following detailed construction plans for fabrication and assembly of the ship. Resolving variations between the detailed plans and actual ship production issues is referred to as 'redlining' the drawings to record how actual fabrication and assembly deviate from the engineering plans. This process can be time consuming causing delays in construction as project managers and architects identify the variance on the shop floor, work to record the variance, work out a solution, correct and re-issue plans, and eventually deliver the corrected plans to front line production workers.

In early 2016, Vigor's Naval Architect developed a mobile application that allows front line workers to access the production plans on a mobile device, capture photographs of the variance, narrate the issues creating the variance, and make redline recommendations on the electronic plans. Upon completion of these activities the redline report is immediately broadcast to all production, management and design team members who can quickly collaborate via the red line app to resolve the issues. In the past this process could have taken days to identify, resolve and record variances to the plans. With the redline app, this process can often be completed in a matter of hours with far less labor and disruption than required for traditional redline resolution of variances.

On another front, Vigor Alaska has set a goal of having zero recordable safety incidents so that all of its employees go home every night in the same condition they were when the work day started. A number of years ago, Vigor Alaska instituted a Near Miss report. It is incumbent on all Vigor employees to file a near miss report when they observe an unsafe condition anywhere in the shipyard.

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In 2014 the near miss reports were recorded by hand on a paper. Photographs of the condition needed to be transferred to the form, and then all of the documentation was collated, copied and finally distributed often taking hours or even days to complete the process for distribution. Based on the time savings and ease of collaboration created with the redline app, the Vigor team developed a similar mobile application to collect and disseminate near miss events. Using a mobile devie with the redline app, Vigor workers can visually record the event, enter text to narrate the condition and immediately distribute the near miss report to all employees, all without having to leave the shop floor. Vigor Alaska's focus on safety in combination with the mobile near miss application has dramatically reduced the annual recordable injuries in Ketchikan. Vigor experienced 3 recordable injuries in the 1st quarter of 2016. The mobile near miss reporting app was introduced in April, and as of today, seven months later, Vigor has had 1 recordable incident.

In another arena, shipbuilding is a complex undertaking with thousands of tasks all interdependent on being performed correctly at the correct time. Typical shipbuilding schedules are constantly shifting in response to the actual progress of work occurring on the shop floor. Early in the AMHS ferry construction project, Vigor initiated an 8 week planning horizon. There are 17 workstations where fabrication of vessel components occurs. Every morning supervisors from the 17 work stations meet to share progress or delays that are occurring at each work station. Each supervisor's comments were recorded on sticky notes with different colors to denote which crafts were performing or promising to perform work for that day. The sticky notes were placed on large schedule boards one for each day. Photographs of the schedule boards were taken and the data was then manually entered into spreadsheets a labor intensive, time consuming process with potential for errors in recording and not accessible until all data was entered. Data from this scheduling process is used to inform the Schedule Performance Index (SPI) that tells project managers whether we are ahead or behind on progress toward completion of the project.

In early 2016, Vigor was made aware of an inexpensive mobile application that has replaced the thousands of sticky notes and schedule boards required for the manual approach to scheduling. Today, like the redline and near miss mobile applications described above, front line supervisors are able to update the planning schedule and immediately notify the entire production team of changes to the daily schedule of work. The speed and ease of collecting this complex data improves the accuracy of the SPI.

In less than a year, mobile devices that were once discouraged for use in the work place are now encouraged for use as tools to increase Vigor Alaska's pursuit of competitive advantage.

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b. What are the greatest challenges for you to overcome in the advanced shipbuilding marine industry?

Answer: In the face of foreign subsidization of other national shipbuilding sectors, the Jones Act has enabled the US commercial shipbuilding industry to attract new investment in advanced manufacturing. Continued national debate and inaccurate information about the Jones Act creates uncertainty about the future of US shipbuilding and hinders new investment in the sector.

Unlike the well-funded federal agencies that support federal highways, transit, rail and aviation infrastructure with multi-billion dollar budgets, marine transportation has funded the Maritime Administration (MarAd) with only $658 million in its FFY 2015 budget. Both the Maritime Administration and the Shipbuilders Council of America (SCA) have published information in support of the Jones Act, but continued vigilance and clear response to threats to the Jones Act is needed. MarAd's role in explaining the purpose and importance of the Jones Act is essential to the health of the US shipbuilding sector.

As Alaska enters the age of advanced manufacturing in shipbuilding, developing and retaining skilled and competitive workforce is a challenge. The SCA has identified workforce development as a national shipbuilding priority. Since shipbuilding is a relatively small component of the national and Alaska state economy, securing public workforce investments to match private workforce investments is challenging. There are discussions of including shipbuilding workforce development in MarAd's mission that would require additional MarAd budget.

The MarAd Assistance to Small Shipyards program has been successful in assisting the domestic shipbuilding industry adopt modern production equipment and practices but is meeting only a fraction of demand. MARAD received 118 grant applications requesting $80 million in assistance, far exceeding the $4.9 million made available for the grants.

Another program supporting domestic shipbuilders is the National Shipbuilding Research Program (NSRP). NSRP began as an R&D program in 1971 under the guidance of MARAD (U.S. Maritime Administration). The Program's initial goal was to collaborate with shipbuilders in developing plans for the economic construction of vessels through reduced production costs, acceleration of delivery schedules, and improved shipbuilding methods. In early 1998, NSRP moved to NAVSEA, where funding, administration and management functions were performed. A challenge to NSRP's excellent research work has been a wider dissemination and implementation of NSRP findings. With adequate funding and congressional direction, MarAd could augment its Assistance to Small US Shipyards by assisting in the dissemination and implementation of NSRP research.

As a maritime nation, it would be reasonable to establish federal funding to MarAd at levels that achieves parity with other modes of transportation, and inclusion of shipbuilding and repair as critical components of the nation's maritime industry sector could help overcome workforce and production challenges currently faced by the domestic shipbuilding industry.

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c. Do you believe that new advanced manufacturing techniques will enable great improvements in the development of future ice breakers?

The rate of change in the US shipbuilding industry is accelerating as it must to keep pace with global changes in the industry. US shipbuilders lead the world in producing complex war ships. As polar navigation increases, commercial vessels are already transiting polar routes. Vigor Alaska is working with an Alaska based cruise company interested in refurbishing retired ocean research vessels to be ice strengthened vessels for cruising above the Arctic Circle. In researching the ice strengthening of existing vessels, a composite overlay system was identified that can affordably provide ice strengthening over traditional methods that required extensive reinforcement of internal frames to absorb ice impact loads. The inherent local stiffness of the overlay ensures effective distribution across existing internal frames of any localized peaks in the ice pressure loads.

This is only one example of how advanced manufacturing techniques might enable development of future ice breakers. Already advancements in propulsion, hull shapes and systems to assist in ice breaking, and overall icebreaker design are improving ice breaker performance. Advances in the US manufacturing practices will advance development of US icebreakers.

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Questions for the Record Submitted to Dr. David Williams

Questions from Chairman Lisa Murkowski

Question 1: *It has been reported that we have a growing skills gap between the needs of our national industries and the abilities of our workforce, with two million manufacturing jobs projected to be unfilled by 2025. In what ways are universities preparing students for the strategic needs of the burgeoning U.S. advanced manufacturing industries?*

Your question embodies several issues that are at the heart of national economic and physical security. Manufacturing makes the products that keep us safe as well as the products we trade to keep us economically viable.

In accord with our Land Grant mission, The Ohio State University maintains close ties with its manufacturing stakeholders through individual relationships, industry associations such as JobsOhio, Columbus 2020 and the Ohio Manufacturers' Association; in addition, we partner with national thought-leading organizations such as the Manufacturing USA Institute, the Lightweight Innovations for Tomorrow that Ohio State co-founded and MForesights. Despite the diversity of the missions and constituencies of these groups, we have received remarkably consistent guidance on the skills that will be needed by 21st Century technical workers at all levels. They are summarized below:

Manufacturing is becoming further automated and we must embrace this. The extended automation of factories is rightly seen as disruptive, and for good reason. The number of jobs on the factory floor is likely to reduce dramatically in coming decades. But automated systems invariably produce better products with greater precision and less waste. Massive opportunities exist in these production facilities locating in our region and in the US. Many great careers will increase in the design of products, production systems, and the development of automated systems, their repair and maintenance. Furthermore, manufacturing has the highest economic multipliers of any industry. Investments in production pay for personnel in engineering, design, marketing and sales. Also, significant raw materials and energy must be purchased. Keeping these economic flows and innovation in the US is critical to our economy. Further, the ability to make things is vitally important in times of international conflict, as it was in the 1940s when we manufactured our way to saving the free world. For all these reasons, intense international competition for providing the sites for the next large manufacturing facilities exists. And technical talent is one of the key elements that cause industry to choose one manufacturing site over another.

The most immediate near-term need is in technical staff who can troubleshoot and repair complex automated manufacturing systems. Time and time again industry leaders tell us of the shortages in multi-craft maintenance technicians. These are the technical generalists who can troubleshoot and fix the complex mechanical-electronic-computational-optical systems that are at the heart of modern production. Sometimes these personnel have engineering degrees; often they finish two-year programs and appropriate apprentice training. We also have learned that more engineers are required; industry tells us that they would like our engineering graduates to have more hands-on skills and we have adapted our curriculum accordingly. All of our mechanical engineers now have both mechanical and electrical design and build experience. And the manufacturing leader that bridges the entry-level manufacturing worker and the senior leadership will require updated engineering technology programs to fill that skills gap.

A much more robust and diverse STEM pipeline is required at all levels. Some of our partner companies have developed their own training programs to fill the needs for technical staff. This can be seen as an inadequacy of our STEM pipelines. The Organization for Economic Cooperation and Development released its 2015 Science, Technology and Industry Scoreboard report. It showed the US raked 39th out of 40 countries in per-capita production of STEM graduates. The US needs more engineers, technicians and even business or policy professionals who are cognizant of technical issues. These individuals are those who will provide a robust manufacturing economy and solve the biggest issues or our time (like climate change, and food security).

We see great opportunities in the Land Grant Universities listening hard to what is needed and efficiently responding to regional needs. Ohio State is proud of its heritage as an institution designed to improve skills and provide research related to improving the economy. We are developing new interaction mechanisms to work with industry, such as our Center for Design and Manufacturing Excellence (cdme.osu.edu), our Ohio Manufacturing Institute (omi.osu.edu), which incidentally produces a great podcast series on manufacturing (see *"Manufacturing Tomorrow"* in iTunesU) and other industry-facing research centers. And we are aggressively investing in faculty and facilities that will invent the next generation of manufacturing processes and train the people that will improve and maintain them.

There is increasing awareness of that a technical workforce that is too small, and insufficiently skilled will throttle our export economy. We are heartened that after a period of neglect that there is renewed consensus that American manufacturing is a key to a prosperous regional economy. We applaud federal and state government investments in programs like Manufacturing USA and private-public partnerships like JobsOhio. They both have strong alignment with business and workforce needs and we academics are proud to be strong partners with them.

Thank you for your advocacy on behalf of these issues that support manufacturing. We would be happy to help in any way to help improve the environment for our domestic manufacturers.

Question 2: *The National Network for Manufacturing Innovation (NNMI) plays an integral role in advanced manufacturing, and in many ways it serves as the functional tie between DOE and everyone else involved with research, development and demonstration* *within the advanced manufacturing industries. Please explain how the NNMI works from your perspective, and how it is useful when it comes to innovating advanced manufacturing technologies and processes.*

The National Network for Manufacturing Innovation (NNMI) is a powerful example of federal investment supporting U.S. growth of advanced manufacturing technologies and jobs. Ohio State faculty play an integral role in nearly every active or pending NNMI hub; these hubs bring together the federal government – including the Departments of Energy and Defense, U.S. industrial partners, venture capitalists, universities, and nonprofits across multiple states. And, to reiterate what I stated in my prepared remarks for the hearing record, I would like to thank this committee and all of your Senate and House colleagues for your ongoing support of the NNMI.

At Ohio State, our researchers can point to the NNMI's usefulness in many ways, but our best example is one of the first NNMI projects to be funded by the current Administration – Lightweight Innovations for Tomorrow (LIFT). Ohio State, along with Columbus-based EWI and the University of Michigan, are co-founders of LIFT, which is a $148 million high-tech national manufacturing consortium comprised of industry, universities and nonprofits. LIFT, which is based in Detroit and led by Executive Director Lawrence E. Brown, is expected to create 10,000 new jobs in the Midwest over the next five years while driving innovation and growth for a rapidly expanding lightweight materials industry. LIFT has initiated projects that are driven by industry needs and that engage some of the world's leading academic researchers to address those needs. The project selection process is driven by a rigorous planning and prioritization review to ensure that U.S. taxpayer dollars are invested prudently in the most important and broadly applicable industry needs.

One recently announced LIFT project is a joint aerospace collaboration with The Ohio State University and GE Aviation demonstrating the fact that public/private collaboration speeds up the solution process in advanced manufacturing. The GE Aviation-Ohio State project uses computer analytics to design and then to virtually test titanium's performance in aircraft engines in *silico* rather than in *vitro*. The advantage is that titanium, an expensive alloy, can be produced and thoroughly tested without cycling through a lengthy and expensive trial and error process of building, then breaking, a large number of test parts. This computer-based testing lowers cost and speeds up the design and manufacturing timetable, bringing new products to market faster and with lower design costs, and improving U.S. competitiveness in a global market. I think you would agree that this is a wise use of public dollars.

As you well know, federal agencies support the bulk of basic or early stage research at U.S. universities and federal labs. You will be pleased to know that while federal funding is vital to our R&D efforts, universities also develop alternative funding streams through our own research investments and through industry partnerships to meet the needs of specific sectors.

For example, Ohio State established the Center for Design and Manufacturing Excellence (CDME) after determining industry needs for a product and process innovation center. CDME provides industry with a simple, expeditious way to access the vast array of intellectual research and physical assets of the university and surrounding research community. Building upon our success in standing up this center with university investment, CDME was awarded $6.8 million from the U.S. Department of Commerce and Department of Defense to foster economic stability and growth in Ohio by advancing the global competitiveness of existing defense and commercial manufacturing companies.

Ohio State professor Glenn Daehn and his research team at the Impulse Manufacturing Laboratory developed several new techniques for joining dissimilar materials by utilizing electrical energy from a capacitor bank. Funding from the U.S. Department of Energy and other federal agencies were used to develop the initial concept. Then, by working with CDME, Professor Daehn's team has been contracted by a commercial entity to design an Ultrafast Capacitor for use in a production manufacturing environment.

We have also directly invested heavily in advanced materials and manufacturing under the University's Discovery Themes initiative – a program that focuses on critical societal needs, reflecting Ohio State's mission as a public, urban, land-grant, research university. Each Discovery Theme includes hiring of faculty who will collaborate with existing resident experts across our departments and colleges to address grand challenges. One such grand challenge is the Materials and Manufacturing for Sustainability theme, in which we are hiring thirty new faculty members to accelerate advanced material design and manufacture. We will build on federal investments in the Materials Genome Initiative, whose goal is to accelerate the discovery, manufacture, and deployment of advanced materials in half the time, and at a fraction of the cost, as we currently do. Ohio State's Materials Innovation Greenhouse initiative will build a rapid prototyping and startup incubator on campus that enables materials scientists and engineers at Ohio State to accelerate the transition of their fundamental research results into the manufacture of new materials and to develop new manufacturing processes for joining of these new materials together into structures and products.

Another example of an institutional investment is our Institute for Materials Research (IMR), which was created in 2006 as a campus-wide, multidisciplinary institute that works with Ohio State colleges and departments to facilitate, promote and coordinate research related to the science and engineering of materials. Led by Professor Steve Ringel, IMR has 222 faculty members at seven colleges who participate. IMR is the gateway to materials-allied research and education at Ohio State; and is responsible for the overall development, coordination and advancement of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme program. IMR Industry Challenge Grants are intended to strengthen new collaborations between university researchers and private industry partners in materials-allied research.

A final example of a critical relationship between the university, federal government and industry comes in the area of corrosion. The annual impact of materials corrosion on the U.S. economy is well into the hundreds of billions of dollars. The State of Ohio, and Ohio State in particular, is the historic home and continues to be a center of excellence in corrosion research. With multi-million dollar/multi-year support from the Department of Defense, a consortium of universities and military academies known as the Technical Corrosion Collaboration (TCC) serves to closely align the research goals of military corrosion experts with those of university scientists, to address fleet sustainability while simultaneously training the next generation of corrosion engineers.

To fully capitalize on a revitalized manufacturing sector and the large number high-quality, in demand jobs it will generate, it is imperative that we have a workforce that is well-trained and prepared to fill these jobs. The LIFT Education & Workforce Development team led by Emily DeRocco has developed a federated model that informs national best practices on advanced manufacturing education career pathways. As part of LIFT education and workforce development efforts, the "LIFT Ohio Means Internships & Co-ops 2.5" initiative at Ohio State engages students in real-world work on advanced lightweight metal alloys, manufacturing technologies and design methods that are integral to advanced manufacturing. Out of the 80 internships, 30 are co-located internships involving students, faculty, and industry partners who work together to solve a specific manufacturing issue or project with defined statement of work with industry-driven deliverables. This industry-focused program also taps community college and technical centers and pilot's novel approaches to developing the talent supply chain for manufacturers. These co-op and internship assignments develop a well-trained workforce while exciting students about the career opportunities in 21st century advanced manufacturing.

Question 3: What are the unique types of expertise in advanced manufacturing found in our great research universities and in our national labs? We would like our efforts to be greater than the sum of its parts. Therefore, how do we leverage these valuable resources in a strategic way to eliminate duplication of efforts and maximize return on investment?

Ohio State, like many of our great research universities, has a long history and substantial expertise in supporting the materials research field and training the future materials engineering workforce. Our welding engineering program was established in 1948. Currently we offer the only accredited B.S. Welding Engineering degree in the nation, and also have the only Welding Engineering graduate program, with both masters and PhD degrees offered. Materials joining is a critical enabling technology for manufacturing across a broad spectrum of industries, including the automotive, aerospace, defense, power generation, oil & gas, medical products, electronics, and many others. The economic benefit of new, advanced materials is sometimes often limited or delayed because we first need to figure out how to join them to other materials. Federal investments are directly addressing this challenge. A good example is the National Science Foundation support for the Industry/University Collaborative Research Center (I/UCRC) known as MA2JIC: Manufacturing and Materials Joining Innovation Center. This center seeks to advance the science and technology of materials joining, with a focus on joining of advanced materials. This center is an outstanding example of a successful public-private partnership; federal funds from NSF provide for center administrative operations, and member companies contribute funds that are pooled to address pre-competitive research and technological advances of interest to them. More than 80% of the center's funds come from its over 40-plus members. It is one of the largest and fastest growing I/UCRCs in the nation.

I would like to strongly reiterate that engagement with industry is the hallmark of our land-grant mission at The Ohio State University and our College of Engineering, and the key to ensuring that we leverage the limited and valuable federal resources available, in a strategic way to eliminate duplication of efforts and maximize return on investment. Research and development partnerships with major automotive and aerospace companies date back to the 1940s. Industry's reliance on the engineering talent we produce has existed since Ohio State's birth in 1870. I strongly believe that collaboration with industry is more important today than ever, and the federal government will continue to play an essential role in seeding the fundamental research and fostering this industry-university partnership. Universities are engines of discovery and talent development, and engines need fuel. Federal funding to support and refine fundamental and applied research is that needed fuel, and it catalyzes the innovation pipeline. Growing and sustaining the innovation ecosystem we envision for advanced manufacturing will require concerted efforts across government, industry, and academia.

Question from Senator Mazie K. Hirono

Question: *In 2013 alone, U.S. universities were issued more than 5,200 patents and research performed at universities led to the formation of 818 new start-up companies. I am a supporter of fostering innovation in our universities which is why I introduced the STRONG Patents Act with Senators Coons and Durbin. This legislation targets abuses in the patent system without hamstringing the ability of patent holders, such as universities, to enforce their rights. Can you comment on how important it is for institutions such as Ohio State to enforce their patent rights so that they can partner with the private sector through technology transfer programs and licensing agreements?*

With over 800 startups formed by universities, more than 5,000 patents issued and 5,000 licenses executed, in addition to $2.6 billion in license income – this is a very important issue to American research universities.[1] Indeed, intellectual property rights are one of the strongest areas where the United States is globally competitive in terms of international trade. The U.S. has a large trade surplus in IP licenses, but the trends are not favorable to the U.S. in terms of new patent applications, patent-eligible subject matter, difficulty of obtaining injunctions, and the high invalidation rate of the Patent Trial and Appeal Board (PTAB) – all substantial factors contributing to depressing the value of patent licenses and cause potential licensees to not bother taking a license.

As you know, Senators Chris Coons (D-DE), along with co-sponsors Dick Durbin (D-IL) and Mazie Hirono (D-HI) submitted The Support Technology and Research for Our Nations Growth Patents Act, or the STRONG Patents Act, on March 3, 2015. The STRONG Patents Act would make a variety of changes to post grant administrative proceedings that the Patent Trial and Appeal Board (PTAB) of the United States Patent and Trademark Office (USPTO), including requiring the PTAB to abandon the broadest reasonable interpretation standard (BRI) and mandating that claims be presumed valid. The Act would also eliminate fee diversion, make it easier to obtain willful damages, make divided infringement actionable even if not all steps are practiced by a single entity, and give the Federal Trade Commission (FTC) greater ability to go after those who send fraudulent or misleading demand letters, but creates a good faith defense. The bill would also eliminate Form 18 of the Federal Rules of Civil Procedure, which has already been proposed by the Judicial Conference[2].

From our perspective and analysis, the bill is primarily focused on combating the view that valid patents are weakened by post-issuance proceedings (and the threat thereof) before the PTAB. In particular, the STRONG Patents Act of 2015 mirrors the Innovation Act and the PATENT Act by requiring the PTAB, in disposing of claim construction in inter parties review (IPR) and post-grant review (PGR), use the "ordinary and customary meaning" standard instead of the "broadest reasonable interpretation" standard. Further, the bill requires the PTAB to consider previous construction of the claims or claim terms at issue by a court, provided the patent owner was a party to the prior civil action. Still further, an issued patent being challenged would enjoy the presumption of validity. The provisions effectively bring post-issuance proceedings in line with federal court litigation in an attempt to slant post-issuance proceedings in favor of the patent owner. The STRONG Patents Act of 2015 also includes lowering the standard for a finding of willful infringement to a preponderance of the evidence. The bill also creates a cause of action under the Federal Trade Commission Act for sending a demand letter in bad faith. The Act also contains, among others, provisions related to micro-entity status for universities and other institutions of higher learning, one-year time limit for ex parte reexamination following service of a complaint, and lowering the standard for proving induced infringement. Of note, the STRONG Patents Act of 2015 does not contain fee-shifting or joinder provisions.

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[1] Table 1 - 2015 AUTM Briefing Book
http://www.autmvisitors.net/sites/default/files/documents/AUTM%20Briefing%20Book%202015.pdf

[2] IP Watchdog - http://www.ipwatchdog.com/2015/05/07/patent-reform-101-a-primer-on-pending-patent-legislation/id=57529/

It is worth noting that the STRONG Patents Act is similar to several other pending pieces of legislation in the House of Representatives. More specifically, the Innovation Protection Act reintroduced by Congressman John Conyers (D-MI) would similarly put an end to fee diversion. The TROL Act also seeks to target fraudulent and abusive demand letters. The STRONG Patents Act is supported by the Biotechnology Industry Organization (BIO), the Innovation Alliance, and at least several major university groups.

- The 1980 Bayh-Dole act has been a huge success in fostering innovation and job growth for our nation and at the heart of that has been university research and inventions.

- Studies have shown that more than 80% of new drug discovery has happened from public sector research and not based on research done by pharmaceutical industry. Protecting those inventions through patents will ensure that these inventions can be taken to market and save lives.

- Universities have a strong and justified economic and social interest in protecting innovation and seeing that substantial exclusive rights are granted to those that innovate and patent.

- Universities are not properly viewed as the "free research arm" for any corporate interest. Given that patent is a negative right of excluding others that the constitution has created, any patent owner, including the universities should have the option of exercising such rights.

- In recent years, universities have been labeled as non-practicing entities (NPE) and patent trolls. This labeling is misguided.

    - We have a very different mission than other entities, based on the Bayh-Dole act our mission is to take technologies to market positively impacts lives and provide value back to our taxpayers.

    - Any return that the university gets back from the patent licenses enriches our research in a positive way.

  - Universities do not acquire patents from others and assert those patents like Patent Assertion Entities (PAEs).

- In certain instances, it become imperative to assert the university's patent right to derive fair value of the technology with a licensee or in other instances just to get a licensee to license a technology. This is no different than the rights provided to an individual or corporate patent holder.

- We believe innovation will suffer if our patents system is further weakened by ill-conceived legislation promoted by those that want to compete based on the strength of their balance sheet rather than the strength of their innovation.

- Ohio State has launched 59 startups which are currently active, of them 45 have been created over the last 3 years, all of which were based on patented innovation. These startups will not be able to attract the funding they desperately need if there are not strong patents to protect innovation.

- For this and other reasons we strongly support the STRONG Patents Act.

Question from Senator Shelley Moore Capito

Question: One of my foremost priorities, as is a priority of all of my colleagues in the Senate, is economic development in our states. Manufacturing is one of the potential keys to boosting economic growth in West Virginia. However, as manufacturing evolves into the use of more advanced techniques, we are going to need to prepare our workforce to meet the demands of these new techniques.

- What are some of the most common new skills and technical knowledge that are needed to succeed in this changing manufacturing landscape?

Your question embodies several issues that are at the heart of national economic and physical security. Manufacturing makes the products that keep us safe as well as the products we trade to keep us economically viable.

In accord with our Land Grant mission, The Ohio State University maintains close ties with its manufacturing stakeholders through individual relationships, industry associations such as JobsOhio, Columbus 2020 and the Ohio Manufacturers' Association; in addition, we partner with national thought-leading organizations such as the Manufacturing USA Institute, the Lightweight Innovations for Tomorrow that Ohio State co-founded and MForesights. Despite the diversity of the missions and constituencies of these groups, we have received remarkably consistent guidance on the skills that will be needed by 21st Century technical workers at all levels. They are summarized below:

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Manufacturing is becoming further automated and we must embrace this. The extended automation of factories is rightly seen as disruptive, and for good reason. The number of jobs on the factory floor is likely to reduce dramatically in coming decades. But automated systems invariably produce better products with greater precision and less waste. Massive opportunities exist in these production facilities locating in our region and in the US. Many great careers will increase in the design of products, production systems, and the development of automated systems, their repair and maintenance. Furthermore, manufacturing has the highest economic multipliers of any industry. Investments in production pay for personnel in engineering, design, marketing and sales. Also, significant raw materials and energy must be purchased. Keeping these economic flows and innovation in the US is critical to our economy. Further, the ability to make things is vitally important in times of international conflict, as it was in the 1940s when we manufactured our way to saving the free world. For all these reasons, intense international competition for providing the sites for the next large manufacturing facilities exists. And technical talent is one of the key elements that cause industry to choose one manufacturing site over another.

The most immediate near-term need is in technical staff who can troubleshoot and repair complex automated manufacturing systems. Time and time again industry leaders tell us of the shortages in multi-craft maintenance technicians. These are the technical generalists who can troubleshoot and fix the complex mechanical-electronic-computational-optical systems that are at the heart of modern production. Sometimes these personnel have engineering degrees; often they finish two-year programs and appropriate apprentice training. We also have learned that more engineers are required; industry tells us that they would like our engineering graduates to have more hands-on skills and we have adapted our curriculum accordingly. All of our mechanical engineers now have both mechanical and electrical design and build experience. And the manufacturing leader that bridges the entry-level manufacturing worker and the senior leadership will require updated engineering technology programs to fill that skills gap.

A much more robust and diverse STEM pipeline is required at all levels. Some of our partner companies have developed their own training programs to fill the needs for technical staff. This can be seen as an inadequacy of our STEM pipelines. The Organization for Economic Cooperation and Development released its 2015 Science, Technology and Industry Scoreboard report. It showed the US raked 39th out of 40 countries in per-capita production of STEM graduates. The US needs more engineers, technicians and even business or policy professionals who are cognizant of technical issues. These individuals are those who will provide a robust manufacturing economy and solve the biggest issues or our time (like climate change, and food security).

We see great opportunities in the Land Grant Universities listening hard to what is needed and efficiently responding to regional needs. Ohio State is proud of its heritage as an institution designed to improve skills and provide research related to improving the

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economy. We are developing new interaction mechanisms to work with industry, such as our Center for Design and Manufacturing Excellence (cdme.osu.edu), our Ohio Manufacturing Institute (omi.osu.edu), which incidentally produces a great podcast series on manufacturing (see *"Manufacturing Tomorrow"* in iTunesU) and other industry-facing research centers. And we are aggressively investing in faculty and facilities that will invent the next generation of manufacturing processes and train the people that will improve and maintain them.

There is increasing awareness of that a technical workforce that is too small, and insufficiently skilled will throttle our export economy. We are heartened that after a period of neglect that there is renewed consensus that American manufacturing is a key to a prosperous regional economy. We applaud federal and state government investments in programs like Manufacturing USA and private-public partnerships like JobsOhio. They both have strong alignment with business and workforce needs and we academics are proud to be strong partners with them.

Thank you for your advocacy on behalf of these issues that support manufacturing. We would be happy to help in any way to help improve the environment for our domestic manufacturers.

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Questions from Chairman Lisa Murkowski

Question 1: In relation to advanced manufacturing, how must the U.S. economy evolve in order to meet the challenges of global competitiveness?

Two areas immediately come to mind. First, we need to support efforts to enable the domestic scaling up of nascent manufacturing businesses—often referred to as the second valley of death. Manufacturing hubs and collaborations between industry, academia and national labs are important parts of this effort, as in the continued access to capital and supportive tax and regulatory incentives. The second area is the importance of developing and supporting skilled talent in new areas of manufacturing such as bio manufacturing and advanced materials.

Question 2: In your written testimony, you mention that the oil and gas boom happening right now in the U.S. has given us a "critical cost advantage." Specifically, countries like China, Japan, and Korea pay about three times what U.S. producers do for natural gas. In your view is that a sustainable advantage for U.S. advanced manufacturing industries? What happens to the "more than $160 billion" in chemical company new investment in the U.S. if our natural gas price advantage diminishes?

No, it is not a sustainable advantage; it is a window of opportunity that we should seek to capitalize upon.

Questions from Ranking Member Maria Cantwell

Questions: Ms. Wince-Smith, as you know, a skilled workforce is a critical component for a productive economy. The need for skilled workers and training, particularly in manufacturing, is increasing.

A recent survey of business executives by Deloitte found that executives rank talent driven innovation as a top driver of a country's ability to compete globally, but U.S. companies are only investing half the amount in job training they did a decade ago.
If we're going to remain competitive in this increasingly globalized economy, we need to get companies to start making these investments in worker training once again

Do you see this drop in investment by companies in worker training as a temporary issue or a permanent feature?

I believe it to be a more permanent trend as the workforce has become more flexible and transient. It is difficult for companies to make major training commitments to employees who are as likely to leave after a year as to stay long term.

How do we incentivize more companies to invest in worker training?

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I suggest that the key is greater collaboration/coordination between industry and academia at the high school and college levels. We need there to be clearer pathways to employment and greater communications as to the jobs, opportunities at companies and skills that they require.

Question from Senator Shelley Moore Capito

Question: Infrastructure is one of the main components of being able to accommodate manufacturing jobs in our communities. One of the other focal points of my tenure in the Senate has been improving broadband infrastructure in West Virginia. Far too often we see our rural communities, schools, and businesses lagging behind the rest of the country due to poor broadband connectivity – which arguably has become as essential as roads, reliable electricity, and running water – as a necessary utility in today's economy.

- How does broadband connectivity affect a community's ability to attract advanced manufacturing jobs?

With the proliferation of sensors and big data analytics as key parts of the advanced manufacturing apparatus, broadband will become even more central to being able to attract and retain new advanced manufacturing industries. I would caution, however, that broadband also enables more jobs to be unburdened by location, so less-skilled positions are more easily outsourced.